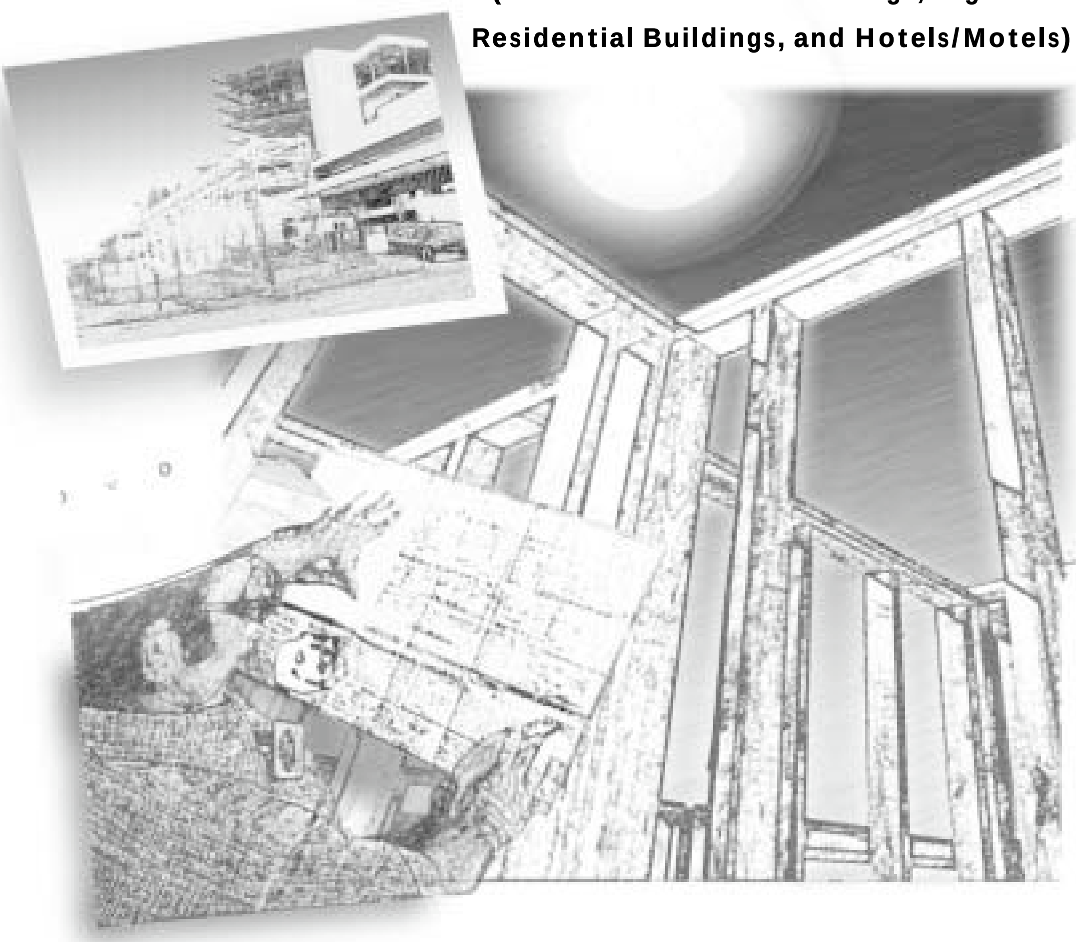
NONRESIDENTIAL MANUAL

for Compliance with the

2001 ENERGY Efficiency Standards

(for Nonresidential Buildings, High-Rise Residential Buildings, and Hotels/Motels)



CALIFORNIA ENERGY COMMISSION

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Abstract

Section 25402.1 of the Public Resources Code requires that the California Energy Commission (Commission) make available compliance materials, including an energy conservation manual. The *Nonresidential Manual for Compliance with the 2001 Energy Efficiency Standards* (*Manual*) is provided to meet the requirement of this Public Resources Code section. This *Manual* supersedes *the Nonresidential Manual for Compliance with the 1998 Energy Efficiency Standards*, and all other previous manuals, notices, and interpretations explaining compliance with the *Energy Efficiency Standards* (*Standards*) for Nonresidential Buildings, High-Rise Residential Buildings and Hotels/Motels.

The Manual includes compliance method descriptions, calculation procedures, technical data, and examples, for meeting the *Standards* for Nonresidential Buildings, High-Rise Residential Buildings, and Hotels/Motels. The chapters in this *Manual* refer to, paraphrase, or quote the *Standards* as adopted by the Commission in the *California Building Code*, Title 24, 1 and 6. When quoted in this Manual, *Standards* language is shown in *italics*. This *Manual* is not a substitute for the Standards, and it should be used in conjunction with a current copy of the *2001 Energy Efficiency Standards*.

Acknowledgments

Acknowledgments

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The Nonresidential Manual has evolved over the years with contributions made by many persons along the way. The 2001 Manual was adapted from earlier versions in response to a mandate by the California legislature in the form of Assembly Bill 970. This most recent version was edited and produced by Eley Associates. Charles Eley wrote much of the new material and served as the technical editor with assistance from Mark Hydeman of Taylor Engineering. Anamika Prasad provided coordination, graphics, and document production. Contributors from the CEC include Tav Commins, Gary Flamm, Jonathan Leber, Bill Pennington, Nelson Peña, Maziar Shirakh, and Ram Verma.

Technical Assistance

The authors are grateful to many people and organizations that contributed to the development and production of this manual. The manual reflects, to a large extent, the comments made by the many people who took time to carefully review earlier versions. Reviewers who contributed to the content include, Lynn Benningfield, Jim Benney, Lance DeLaura, Martyn Dodd, Gary Farber, Henry Lau, Doug Mahone, Ken Nittler, Dee Anne Ross, Nehemiah Stone.

Lastly, so many others contributed helpful suggestions, and comments that are impossible to show a complete list. However, their assistance is acknowledged and greatly appreciated.

In spite of all our efforts, omissions and errors are certain to occur. These, of course, are attributed to the authors alone. If a Manual user discovers an error or has a suggestion, we request that it be brought to the attention of the Energy Efficiency Hotline at 1-800-772-3300 (California only) or 916-654-5106.

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1 Introduction

1.0 Summary

This chapter is an introduction to the 2001 Energy Efficiency Standards for Nonresidential Buildings, High-Rise Residential Buildings and Hotels/Motels (*Standards*), as well as this Nonresidential Manual (*Manual*). Section 1.1 summarizes the reasons for having energy standards and explains the organization of this *Manual*. This is followed by Sections 1.2 and 1.3 that outline the changes brought about by the 2001 *Standards* and the history of the Standards since their inception in 1978. Section 1.4 introduces the basic approaches to complying with the *Standards*, and briefly discusses some of the compliance options available.

Throughout the *Manual*, sections within this *Manual* are referred to as 'Section', and sections in the *Standard* are represented by "§" (unless the reference occurs within an excerpt from the *Standards*). Definitions in italics are quoted from §101(b) throughout this *Manual*.

1.1 Purpose and Organization of this Manual

This *Nonresidential Manual* is organized into six chapters and several appendices. Each chapter of the *Manual* covers a major set of related topics regarding compliance with the requirements of the *Standards*.

Chapter** 1,* this *Introduction,* serves as a brief overview of the *Standards* and this *Manual.* ***Chapter 2***,*** discusses the *Scope and Application* of the *Standards*, explaining when they apply to a particular building and discussing some application problems that may arise. Chapter 2 will help in deciding if the *Standards* apply to the project.

***Chapters** 3, 4 and 5* discuss the *Standards* in terms of the three major components: envelope, mechanical and lighting. These chapters are written to be largely stand-alone for the discipline to which it applies. For example, the HVAC system designer will find all the mechanical system requirements fully discussed in Chapter 4. Likewise, the building department's mechanical plan checker and inspector can concentrate on Chapter 5.

Chapter 6***,*** discusses several *Special Topics* that can apply to any of the components. This includes a discussion of the Performance Approach, High-rise Residential Buildings, and Hotels and Motels.

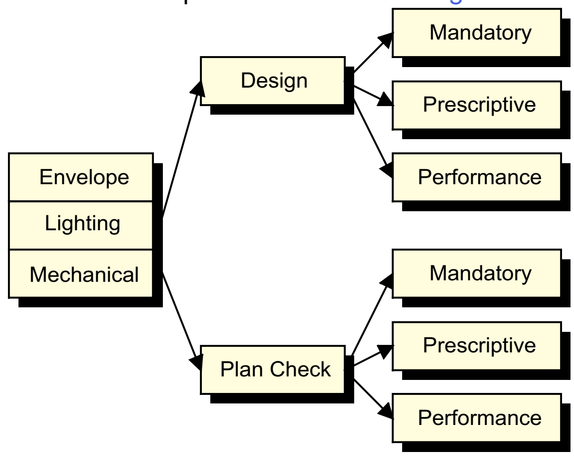
These three chapters are organized into subsections that address the major phases of a building project:

- The *Design* section discusses the requirements as they affect the design process; the principles of each requirement are explained and illustrated.
- The *Plan Check Documents* section is addressed to those who prepare the construction documents and compliance calculations for review by the building department's plan checker. It is also addressed to the plan checker. This section focuses on the specific information that must be included in the plans and on the compliance forms to adequately demonstrate compliance.

Each of the sections addresses the Mandatory Measures, the Prescriptive Approach and the Performance Approach.

The organization of these three chapters is illustrated in Figure 1-1.

Figure 1-1: Organization of Chapters 3, 4 and 5



In addition to the major parts of these three chapters, there are two sections at the beginning of each chapter.

Summary provides a brief overview of the chapter contents.

Introduction provides basic information about the component and its compliance requirements:

Compliance Approaches explains the options available for compliance for the given building component.

Basic Concepts explains the definitions and technical concepts necessary to an understanding of the *Standards* requirements applicable to the component.

Appendices contain reference tables, charts, and definitions that support the implementation of the *Standards,* including data on construction assemblies, and Climate Zone Descriptions.

Tables of Contents and Index - at the front and back of the Manual - provide cross-references to the material in the document.

Note: Two notation conventions are used throughout this Manual in making cross-references:

1. References to other locations within this Manual are called out by Section number: “see Section 3.2.2D”

2. References to the 2001 Energy Efficiency Standards are called out by section “§” number: “§143(b)”

1.2 Summary of Recent Changes

This section describes recent events in California and how the standards have changed in response to these events.

1.2.1 California's Energy Crisis and Assembly Bill 970

In the summer of 2000, California experienced rolling blackouts in the San Francisco Bay area, and electricity bills in San Diego that went up by as much as 300%. These events signaled the beginning of an energy crisis that continued into 2001 with rolling blackouts becoming a common occurrence throughout the state. High-energy prices have depleted the state surplus and caused California's largest utility to file Chapter 11 bankruptcy. At the date of this writing, the State's electrical system continues to be vulnerable to increasing electricity demand, generation supply shortages, transmission constraints, and extremely high wholesale electricity costs caused by an unstable market.

A. Assembly Bill 970

At the close of the 2000 legislative session, the Legislature responded to the crisis by passing AB 970, an urgency statute that became effective when the Governor signed it on September 6, 2000. The statute, known as the California Energy and Reliability Act of 2000, found that there has been significant growth in the demand for electricity and that new power plant construction and energy conservation have seriously lagged. The act provides a balanced response by providing significant investment in conservation and demand-side management programs. In particular, AB 970 added Section 25553 to the Warren Alquist Act, as follows:

> Notwithstanding any other provision of law, on or before 120 days after the effective date of this section or on the earliest feasible date thereafter, the Commission shall . . . (b) Adopt and implement updated and cost-effective standards pursuant to Section 25402 to ensure the maximum feasible reductions in wasteful, uneconomic, inefficient, or unnecessary consumption of electricity.

In response to AB 970, the *Energy Commission* conducted an emergency rulemaking to develop amendments to the Standards, which were adopted by the *Energy Commission* on January 3, 2001(119 days after AB 970 was signed by the Governor). The AB 970 amendments to the Standards focused on reducing peak electricity consumption and demand in the shortest time possible. For consideration in the AB 970 rulemaking, measures had to have the following characteristics:

Substantial information was already available regarding their benefits and costs;

Specifications and eligibility criteria could be developed quickly within the time the Legislature allotted; and

The industry would be able to incorporate the changes on an emergency basis without disruption to construction practice.

B. The Worsening Situation

Since AB 970 was passed by the Legislature and the 2001 Standards were adopted, the reliability of California s electricity system has continued to deteriorate. In his January 2001 State of the State message, the Governor placed highest priority on actions to address what he termed the electricity nightmare. He included the following points in his message: Electricity is a basic necessity of life. It is the very fuel, which powers our high-tech economy. A dysfunctional energy market is threatening to disrupt people's lives and damage our economy. It has resulted in skyrocketing prices and an unreliable supply of electricity, causing the average price per megawatt hour to increase by 900%, compared to last year. By reducing peak demand, we can reduce the price: avoid shortages, and lower energy bills.

In January 2001, power plant outages lead to inadequate electricity supplies in California, causing multiple Stage 3 alerts and rolling blackouts in Northern California. The cost of natural gas also has rapidly increased during this period.

The *Energy Commission* is continuing to update the standards to respond to the energy crisis. Additional enhancements and improvements are being planned for the next update, to be adopted in about July 2004 and take effect in 2005.

1.2.2 Assembly Bill 970 Changes

This section summarizes the 2001 changes to the nonresidential standards that were adopted as part of the AB 970 emergency rulemaking. The most significant changes were updates to the fenestration criteria and additional requirements for NFRC testing of site-built fenestration. In addition, credits for cool roofs were added; exterior lighting requirements were added; several other provisions of the lighting standards were adjusted; HVAC equipment efficiencies were made more stringent; and miscellaneous other additions were made to the HVAC requirements. These are summarized below:

A. Fenestration

The U-factor and SHGC criteria for fenestration were updated. These criteria were last updated in 1992, and at that time, the *Energy Commission* only considered clear and tinted glazing constructions in developing the criteria because of aesthetic issues related to reflective glass as well as cost and availability uncertainties related to low-e coatings. Fenestration technologies have improved in the last 10 years; the markets are more stable. The new *Standards* consider a wide variety of modern glazing constructions, and as result, are more stringent and appropriate. The structure of the standard was also modified so that the SHGC criteria become more stringent with larger window-wall ratios.

Require NFRC testing and labeling for site-built fenestration in nonresidential buildings with more than 100,000 ft² of conditioned floor area and 10,000 ft² of vertical fenestration area. Previously, NFRC had no test procedure for curtain walls and other site-built fenestration products. To meet this requirement, curtain wall suppliers or glazing contractors must have products rated and certified in accordance with the NFRC Site-Built Program.

B. Cool Roofs

A credit for cool roofs is added that can be used with both the prescriptive overall envelope approach and the whole building performance method. Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance assures that when the roof does warm up, its heat can escape through radiation to the sky. Cool roofs were not previously considered in the standards.

C. Lighting

A number of miscellaneous changes were made to the lighting requirements as described below:

Lamps used in exterior lighting applications that are larger than 100 W must have a minimum efficacy of 60 lumens/watt or be controlled by a motion sensor. The requirement will have little impact on compact fluorescents since they are less than 100 W.

Several of the complete building and area category lighting power density allowances are modified to be consistent with ASHRAE/IESNA Standard 90.1-1999. In particular a separate allowance is added for convention centers and the allowance for hotel lobbies and locker rooms is reduced slightly.

The exceptions for bi-level illumination are modified, requiring the control even when an occupant sensor is installed. This will cause the requirement to apply to more cases and increase the ability of building owners to respond to power emergencies.

A loophole for task lighting in office applications is closed. The lighting power allowance for offices was always intended to include task lighting, but task lighting has previously been ignored.

The power credit for lumen maintenance was eliminated since this technology is no longer used.

D. HVAC

A number of changes were made to the HVAC requirements, as summarized below. The most significant of these was to update the minimum equipment efficiencies.

The HVAC equipment efficiency requirements were updated to be consistent with ASHRAE/IESNA Standard 90.1-1999. ASHRAE 1999 had more stringent equipment efficiency requirements than California 1998 for non-NAECA HVAC equipment. The ASHRAE efficiency requirements were justified through life cycle cost analysis, using cost data provided by the manufacturers through their trade organizations, the Air-conditioning and Refrigeration Institute (ARI) and the Gas Appliance Manufacturers Association (GAMA).

Additional mandatory measures were added to mitigate standby losses for gas- and oil-fired forced air furnaces. The requirements include power venting, vent dampers or flue dampers when the equipment is in conditioned space; intermittent ignition or interrupted devices (IID) regardless of location; and limits on jacket losses for furnaces located in unconditioned spaces.

A tradeoff method is added for centrifugal chillers designed to operate at non-ARI standard test conditions.

A prescriptive trade-off table is added for airside economizers that allow higher equipment efficiencies in lieu of an economizer for unitary air-conditioners and heat pumps. This requirement is a modification of a trade-off developed for ASHRAE Standard 90.1-1999, but adapted for the 16 California climate zones.

Requirements are added for the type of high-limit switch, which can be used for air-side economizers. This requirement is based on ASHRAE 1999, but adapted for California climates.

Language is added to the standard to protect pipe and duct insulation that is exposed to outdoor conditions and unconditioned space.

High occupancy spaces, requiring a large quantity of outdoor air, must have demand ventilation controls such as CO_2 sensors to minimize quantities of outdoor air when not needed.

Fan speed controls are required for cooling towers and air-cooled or evaporative cooled condensers.

E. Air Distribution Ducts

The Nonresidential Alternative Calculation Method (ACM) is modified to include the impact of duct leakage and insulation levels on heating equipment efficiency and cooling equipment efficiency for individual packaged equipment serving 5000 ft² or less. The procedure applies only to duct work located in spaces above insulated ceilings and beneath the roof.

1.3 Background

1.3.1 Legal Requirements – The Warren Alquist Act

All new buildings in California must meet the *Standards* and the administrative requirements of the *California Code of Regulations,* Title 24, Parts 1 and 6. Some requirements in the *Appliance Efficiency Regulations* of Title 20, Sections 1601 - 1608, also apply.

The statutory basis for the *Standards* is Section 25402 of the *Public Resources Code,* which states:

The California Energy Commission shall:" Prescribe, by regulation, building design and construction standards that increase the efficiency in the use of energy for new residential and new nonresidential buildings. The standards shall be cost effective, when taken in their entirety, and when amortized over the economic life of the structure when compared with historical practice...."

The purpose of this *Manual* is to explain clearly how to comply with and enforce the current *Standards* for nonresidential buildings. The *Manual* is written as both a reference source and an instructional guide, and can be used by architects, builders, building owners, designers, energy consultants, enforcement agency personnel, engineers, mechanical contractors and others directly or indirectly involved in the compliance process. The *Manual* is divided into six chapters, each describing how the *Standards* apply to specific building components or situations.

Changes to the standards occur periodically to account for improvements in conservation technologies, changes in the cost of fuels and energy-conserving strategies, and improved capabilities in analyzing building energy performance. In addition, modifications are also made to further improve compliance and enforcement.

1.3.2 Benefits of the Standards

There are numerous reasons to use energy more efficiently in buildings. First of all there is a benefit in terms of improving the reliability of our electric systems. Another benefit is improved comfort. Efficiency also makes sense from an economic perspective. Investing in building energy conservation helps ensure that buildings are affordable to operate both now and into the future. The *Standards* also produce environmental benefits, reducing risk of oil spills, acid rain, smog and other forms of pollution. In addition, the energy created by burning fossil fuels may lead to global climate change as a result of the Greenhouse Effect." These and other benefits are discussed in greater detail below.

The National Academy of Sciences has urged the entire country to follow California's lead to "make conservation and efficiency the chief element in energy policy." The first efficiency recommendation was simple: "adopt nationwide energy efficient building codes."

A. Energy Reliability and Demand

Buildings are one of the major contributors to electricity demand. With the 2000/2001 California energy crisis, the importance of conservation and efficiency is brought again to the forefront. The AB 970 changes will result in savings of over 800,000 therms/year of gas and about 100,000 MWh of electricity use. Perhaps more importantly, as much as 150 MW of peak demand of electricity is reduced. Furthermore, these savings are cumulative, which means that they double in two years, triple in three, etc.

B. Comfort

Compelling reasons exist for more efficient energy use in buildings. Comfort is an important reason. If a house is drafty, even a large, modern furnace will not keep it comfortable on a winter day. On a hot summer day no reasonable amount of air conditioning can maintain an appropriate sense of coolness in a room surrounded by clear unshaded glass windows without shading. The mechanical heating and cooling equipment are only part of the overall system that maintains a pleasantly comfortable indoor environment. The building shell (or envelope) is equally important and energy efficiency helps ensure that new homes maintain a reasonable level of comfort.

C. Economics

For the building owner or energy-bill paying building tenant, investing in building energy conservation helps to ensure that energy costs are affordable both now and in the future. Banks and other financial institutions recognize the impact of efficiency through energy efficient mortgages.

From a broader perspective, the less California depends on depletable resources such as natural gas, coal, and oil, the stronger and more stable its economy will remain in the face of increases in costs of these resources. A cost-effective investment in energy efficiency benefits the entire state.

D. Environment Energy efficiency also benefits the local environment. In many parts of the world, the use of traditional sources of energy has led to oil spills, acid rain, smog, and other forms of environmental pollution that have ruined its environment and natural beauty. California is not immune to these problems, but the risks would be greater without appliance standards, building standards, and utility programs that promote efficiency and conservation. Another significant benefit is - reduced destruction of natural habitats, which in turn helps protect animals, plants, and the natural systems.

E. Global Warming Finally, the state faces a major uncertainty—global climate change or global warming. One of the contributors to global warming is a by-product of burning fossil fuel. When fossil fuel is burned- no matter how cleanly- carbon dioxide is added to an atmosphere. The added gas forms an insulating layer on the earth leading to global climate change.

Most scientists agree that the effects of global warming will be significant. According to California Energy Commission (hereafter *Energy Commission*) research, most of the sectors of the state economy face significant risk from climate change including water resources, agriculture, forests, and the natural habitats of a number of indigenous plants and animals.

Most scientists recommend that actions be taken to reduce emissions of carbon dioxide and other greenhouse gasses. While adding scrubbers to power plants and catalytic converters to cars is a step in the right direction, those actions do not limit the carbon dioxide we emit into the atmosphere. Using energy efficiently is a far-reaching strategy that can make an important contribution to the reduction of greenhouse gasses. The National Academy of Sciences urged the whole country to follow California's lead on such efforts, saying that we should make conservation and efficiency the chief element in energy policy. Their first efficiency recommendation was simple: Adopt nationwide energy efficient building codes. Energy conservation will not only increase comfort levels and save homeowners money; it will also play a vital role in creating and maintaining a healthy environment.

1.3.3 History of the Standards

The Legislature created the State Energy Resources Conservation and Development Commission (*Energy Commission*) in 1974 to deal with energy-related issues, and mandated that the *Energy Commission* adopt conservation standards for new buildings. The first standards were adopted in 1977. This was in the wake of the Organization of Petroleum Exporting Countries (OPEC) oil embargo of 1973.

So-called “First Generation” standards for nonresidential buildings took effect in 1978. Those nonresidential standards remained in effect for all nonresidential occupancies until the late 1980s, when the “Second Generation” standards took effect for offices, retail and wholesale stores.

The next major revision occurred in 1992 when the requirements were simplified and consolidated for all building types. At this time, major changes were made to the lighting requirements, the building envelope and fenestration requirements, as well as the HVAC and mechanical requirements.

Table J-1 in Appendix J summarizes the *History of the Standards and Manuals* in effect since 1978 and lists the name of the compliance manual that was used in conjunction with that set of standards.

1.4 Introduction to the Standards

The *Standards* provide flexibility to the designer by providing several paths to standards compliance. This section introduces the basic choices, or approaches, that are available. The details of how the different approaches apply to the building and its systems are covered in the following chapters.

There are two basic options for demonstrating that a building meets the requirements of the *Standards:* the prescriptive approach and the performance approach. With either approach, certain mandatory measures always apply.

The *Standards* cover the three major components of a nonresidential building: the building envelope, the mechanical systems, and the lighting systems. A minor energy user, water heating, is also covered. Each component is typically the responsibility of a different design professional. The envelope is designed by an architect, the mechanical systems by a mechanical engineer, and the lighting systems by an electrical engineer. Each of the three components may be shown to comply independently under the prescriptive approach. Under the performance approach, *Standards* compliance may be shown for the envelope only, the envelope and mechanical systems, or for all three components together.

The building (all three components) may be shown to comply as a whole under the performance approach only when the permit application includes all three components.

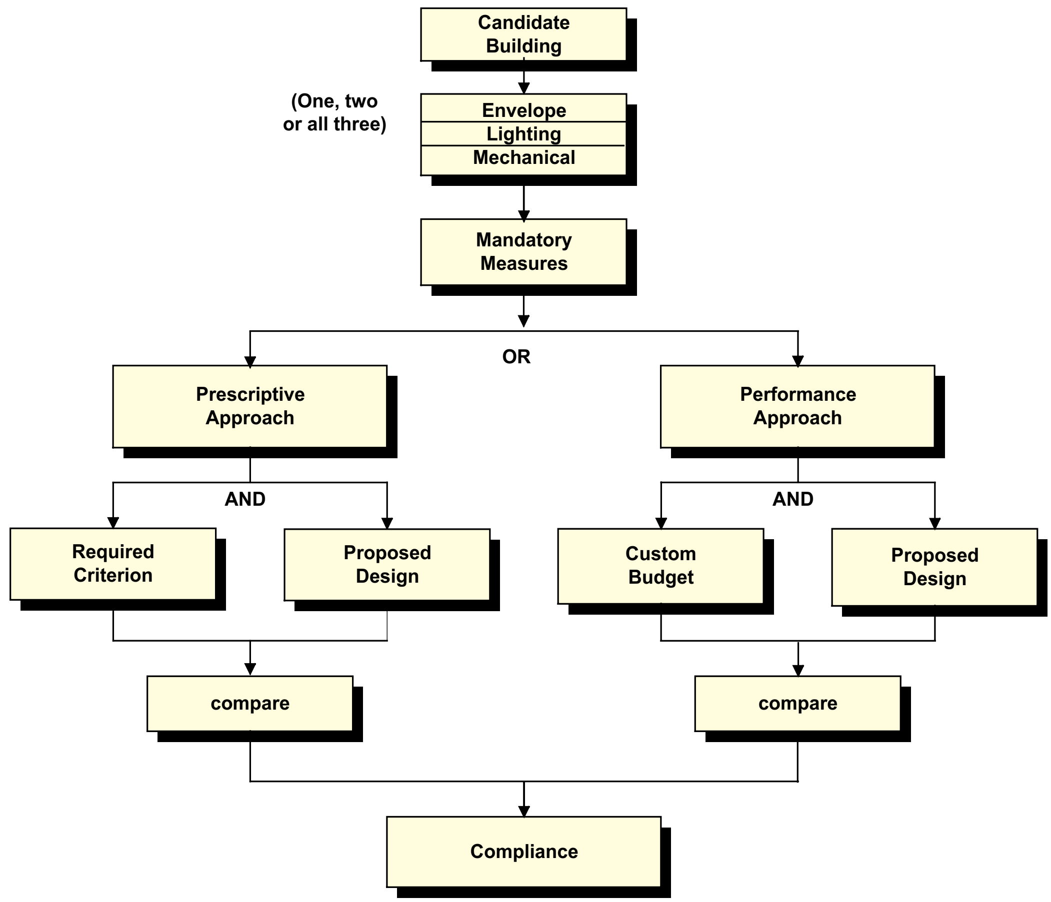
Figure 1-1 graphically illustrates how the three nonresidential building components must each comply with their mandatory measures, and then, either the prescriptive or performance approaches.

The mandatory measures for each of the three components are described in Chapters *3, 4 and 5* of this Manual. In addition Chapter 6 includes mandatory measures for High-Rise Residential and Motel/Hotel.

The prescriptive approach is the simpler way to comply with the *Standards*. Each of the three building components complies separately from the others. The compliance procedures and documentation are also separate for the three.

The prescriptive approach for each component requires that the proposed system design be shown to meet specific energy efficiency criteria specified by the *Standards*. If the design fails to meet even one of the requirements, then the component does not comply with the *Standards*. The performance approach provides the most flexibility to the building designer for choosing alternative energy efficiency features.

Figure 1-2– Nonresidential Standards Flowchart



1.4.1 Organization of the Standards

The organization of the *Standards* is shown graphically in Table 1-1.

Table 1-1 Organization of the Standards

- Title 24, Part 1, Article 1 - Administrative Requirements
- Title 20, Sections 1601 et seq. - Appliance Efficiency Regulations
- Title 24, Part 6, - Energy Efficiency Standards
  - Subchapter 1 - General Provisions – All Occupancies
    - 100 – Scope
    - 101 - Definitions and Rules of Construction
    - 102 - Calculation of Source Energy Consumption
  - Subchapter 2 - Mandatory – Equipment Manufacture & Installation of Systems and Equipment – All Occupancies
    - 110 - Systems and Equipment - General
    - 111 & 112 - Appliances and Space Conditioning Equipment
    - 113-115 - Water Heaters, Pools & Spas, Natural Gas, Pilot Lights
    - 116-118 - Doors, Windows, Joints Insulation and Cool Roofs
    - 119 - Lighting Control Devices
  - Subchapter 3 - Mandatory – Mechanical Systems and Equipment – Nonresidential, High-rise Residential, and Hotel/Motel Occupancies
    - 120 - Space Conditioning and Water Heating Systems and Equipment - General
    - 121 - Requirements for Ventilation
    - 122 - Required Controls for Space Conditioning Systems
    - 123-124 - Requirements for Pipe and Duct Insulation
  - Subchapter 4 - Mandatory – Lighting Systems and Equipment – Nonresidential, High-rise Residential, and Hotel/Motel Occupancies
    - 130 - Lighting General
    - 131 - Required Lighting Controls
    - 132 - Lighting Circuiting
  - Subchapter 5 - Performance and Prescriptive Approaches – Nonresidential, High-rise Residential, and Hotel/Motel Occupancies
    - 140 - Choice of Performance/ Prescriptive
    - 141 - Performance Budgets
    - 142 - Prescriptive Approach
    - 143 - Prescriptive Envelope
    - 144-145 - Prescriptive Mechanical
    - 146 - Prescriptive Lighitng
  - Subchapter 6 - Additions, Alterations and Repairs – Nonresidential, High-rise Residential, and Hotel/Motel Occupancies
    - 149 - Additions, Alterations and Repairs
  - Subchapters 7 & 8 - Low Rise Residential Buildings
    - 150-152 - Mandatory, Performance & Prescriptive, Additions and Alterations

1.4.2 Which Standards Apply? Nonresidential vs. Residential

The California standards apply to both nonresidential and residential buildings. This manual addresses the requirements for nonresidential buildings, including hotels, motels, and high-rise residential buildings (those over three stories in height). A companion manual addresses the requirements for low-rise residential buildings. Live-Work buildings are a special case (see Mixed Occupancy in Section 2.2).

Table 1-2 Nonresidential vs. Residential Standards

Nonresidential Standards	Low-Rise Residential Standards
These standards cover all nonresidential occupancies (Group A, B, E, F, H, M or S), as well as high-rise residential (Groups R-1 and R-2 with four or more habitable stories), and all hotel and motel occupancies.	These standards cover all low-rise residential occupancies including:
Applicable compliance manual: This *Nonresidential Manual for Compliance with the Energy Efficiency Standards*, *August 2001.*	Applicable compliance manual: The *Residential Manual for Compliance with the Energy Efficiency Standards*, *August 2001.*
Offices Retail and wholesale stores Grocery stores Restaurants Assembly and conference areas Industrial work buildings Commercial or industrial storage Schools and churches Theaters Hotels and motels Apartment and multi-family buildings, and long-term care facilities (group R-2), with four or more habitable stories	All single family dwellings of any number of stories (Group R-3) All duplex (two-dwelling) buildings of any number of stories (Group R-3) All multi-family buildings with three or fewer habitable stories (Groups R-1 and R-2) Additions and alterations to all of the above buildings
Note: The *Standards* define a habitable story as one that contains space in which humans may live or work in reasonable comfort, and that has at least 50 percent of its volume above grade. Copies of the compliance manuals and other relevant publications may be obtained from the *Energy Commission* - call the Energy Efficiency Hotline for the latest update at 916-654-5106 or 1-800-772-3300 (in California only).	

The current *Standards* (2001 Edition) generally apply to all *Uniform Building Code (UBC)* occupancies of Group A, B, E, F, H, M, R and S buildings that are *mechanically heated or mechanically cooled* resulting in *directly* or *indirectly conditioned space*. Nonresidential buildings that have space conditioning, but do not meet the criteria of a directly or indirectly conditioned building, must comply with the lighting requirements only. Group I or U occupancies are exempt from the *Standards.* The exempt occupancies include buildings such as hospitals, prisons and residential garages.

1.4.3 California Climate Zones

Since energy use depends partly upon weather conditions, which differ throughout the state, the *Energy Commission* has established 16 climate zones representing distinct climates within California (see Figure 1-2). These 16 climate zones are used with both the Residential and the Nonresidential *Standards*.

Detailed climate zone boundary descriptions and lists of locations within each zone are available in the *Energy Commission* publication\ California Climate Zone Descriptions for New Buildings, July 1995, (P400-95-041), and are included in this *Manual* as Appendix C.

Note: Cities may occasionally straddle two climate zones. In these instances, the exact building location and correct climate zone should be verified before any calculations are performed.

If a single building is split by a climate zone boundary line, it must be designed to the requirements of the climate zone in which 50 percent or more of the building is contained.

Figure 1-3–California Climate Zones

1.4.4 Nonresidential Compliance Approaches

A. Prescriptive Approach

Building Envelope The prescriptive envelope requirements are determined either by the Envelope Component Approach or the Overall Envelope Approach. These two approaches are described in detail in Chapter 3, beginning with an introduction in Section 3.1. The stringency of the envelope requirements varies according to climate zone and occupancy type.

Mechanical The prescriptive mechanical requirements are described in detail in Chapter 4. The prescriptive *Standards* do not offer any alternative approaches, but specify hardware features and design procedures that must be followed.

Lighting The prescriptive lighting requirements are determined by one of three methods: the Complete Building Method, the Area Category Method, or the Tailored Method. These three approaches are described in detail in Chapter 5, beginning with an introduction in Section 5.2.2. The allowed lighting under the *Standards* varies according to the requirements of the particular building occupancy or task requirements.

1.4.5 Performance Approach

The performance approach allows a wider variety of design strategies and provides greater flexibility than the prescriptive approach. It is based on an energy simulation model of the building. The *Standards* specify the method for determining an energy budget for the building. This is known as the *custom energy budget,* because it is generated on a case-by-case basis. This energy budget represents the upper limit of energy use allowed for that particular building.

Four basic steps are involved:

- Design the building with energy efficiency measures that are expected to be sufficient to meet the energy budget. (The prescriptive approach requirements provide a good starting point for the development of the design.)
- Demonstrate that the building complies with the mandatory measures (see Chapters 3, 4, 5 and 6).

  Using an approved calculation method, model the energy consumption of the building using the proposed features to create the proposed energy budget. The model will also automatically calculate the allowed energy budget for the proposed building

If the proposed energy budget is no greater than the allowed energy budget, the building complies.

The designer is permitted to trade off different aspects of the building design, one against the other, when permit applications for more than one component are submitted at the same time. As long as total energy use considering all installed components does not exceed the allowed budget, the tradeoff is acceptable.

2 Scope and Application

2.0 Summary

This chapter discusses when and how the *Standards* (§100(a)1, 2, 3) apply to a building. Section 2.1 presents the basic scope of the *Standards.* It explains the definitions that must be understood to have a precise understanding of the scope and application. Section 2.2 explains some of the key terms used for defining the scope and application of the *Standards*. This chapter does *not* discuss the specific requirements of the *Standards*; these are discussed in Chapters 3*,* 4*, and* 5.

2.1 Introduction (§100(a)1, 2, 3)

The *Standards* apply to any new construction that requires a building permit, whether for an entire building or for adding a few lighting fixtures (§100). The primary enforcement mechanism of the *Standards* is through the building permitting process. Until the building department is satisfied that the building complies with all applicable code requirements, including the energy *Standards,* it may withhold the building permit (or, after construction, the occupancy permit).

The *Standards* apply only to the construction that is the subject of the building permit application (with the exception of existing spaces that are "conditioned" for the first time, in which case existing envelope and lighting systems also must show compliance with the *Standards*).

The *Standards* apply only to buildings that are *directly, indirectly or semi-conditioned* by *mechanical heating* or *mechanical cooling (*§100(a)). Section 2.2 provides detailed definitions of these terms.

2.1.1 Nonresidential Standards

The *AB 970 Energy Efficiency Standards for Residential and Nonresidential Buildings* went into effect on June 1, 2001. 'Nonresidential' buildings include nearly all buildings that are not low-rise residential buildings. These include the following Uniform Building Code Occupancy Groups:

UBC Groups A, B, E, F, H, M, R (limited), and S.

These buildings include (but are not limited to):

- Offices
- Retail and wholesale stores
- Grocery stores
- Restaurants
- Assembly and conference areas
- Industrial work buildings

- Commercial or industrial warehouses
- Schools
- Churches
- Theaters
- Apartment buildings with four or more habitable stories
- Hotels and Motels

The *Standards* do not apply to UBC Groups I and U. These groups include such buildings as hospitals, daycare, nursing homes, prisons, private garages and agricultural buildings.

The *Standards* also do not apply to buildings that fall outside the jurisdiction of California building codes, such as mobile structures.

The final exception to the *Standards* is qualified historic buildings, as defined in the State Historic Building Code (Title 24, Part 8, Exception to §100(a)).

Table 2-1(Table 1-A of the *Standards*) below summarizes the application of the *Standards*.

Table 2-1 Applications of Standards

Building Type	Mandatory	Performance	Prescriptive	Additions/Alterations
All Occupancies	§100 through §109 and §118	—	—	—
Nonresidential, high-rise residential, and hotels/motels				
All	§102, §110 through §139	§141	§142 through §146	§149
Envelope	—	§141	§143	§149
Mechanical	§120 through §129	§141	§144 and §145	§149
Lighting	§130 through §139	§141	§146	§149
Semiconditioned nonresidential buildings of an occupancy group listed in §100	§119, §130 through §139	—	§146	§149 (b) 3
Low-rise residential	§102, §110 through §118, and §150	§151 (a) through (e)	§151 (a), (f)	§152

Example 2-2 - Research Greenhouse

Question

A company engaged in agricultural research has a greenhouse appended to its office building. It is devoted exclusively to cultivating exotic plants and is conditioned to maintain a set temperature of 80°F. Is it subject to glazing restrictions and envelope heat gain limits?

Answer

It depends upon the UBC Group designation of the greenhouse. If it is designated an agricultural building (Group U), then it is exempt from the *Standards*. If it is designated part of the B office occupancy, then it would be subject to the applicable glazing, lighting and other standards.

2.1.2 Residential Standards

The *AB 970 Energy Efficiency Standards for Residential and Nonresidential Buildings* also apply to low-rise residential buildings (effective June 1, 2001). The *Standards* cover single-family and low-rise residential buildings (occupancy groups R1, R2, and R3) including:

- All single-family dwellings of any number of stories
- All duplex (two-dwelling) buildings of any number of stories
- All multi-family buildings with three or fewer habitable stories (Groups R-1 and R-2)
- Additions and alterations to all the above buildings

The applicable design manual for those buildings is the *Residential Manual for Compliance with the AB 970 Energy Efficiency Standards for Residential and Nonresidential Buildings.*

Copies of the compliance manuals and other relevant publications may be obtained by contacting the *Energy Commission* (see Appendix F).

2.2 Basic Scope and Application Concepts

The following discussion explains the definitions of the key terms for understanding the scope and application of the *Standards*. In most cases, a careful reading of these definitions will resolve questions of interpretation. These definitions are located in §101 of the *Standards;* italicized words below indicate the wording taken verbatim from that section.

2.2.1 Conditioned Space Definitions

Building *is any structure or space for which a permit is sought.* By this definition, a building is not necessarily a complete physical structure. For the *Standards,* a building in this sense can be a lighting system recircuiting project, because this would require an electrical permit.

Conditioned Floor Area (CFA) *is the floor area (in square feet) of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space.* Once the spaces that are directly or indirectly conditioned are identified, then it is possible to calculate the conditioned floor area of the building. This number is used for various calculation purposes in complying with the *Standards.* The CFA is generally calculated from dimensions on the floor plans of the building. It is measured from the outside surfaces of exterior walls, with the dimensions taken at floor level. This definition helps mitigate any complexity from sloping walls, bay windows and other unique building details.

Conditioned Space *is space in a building that is either directly conditioned, indirectly conditioned or semi-conditioned.* In most circumstances it is obvious whether a space is conditioned or semi-conditioned. There are, however, special circumstances that require a closer look at the definitions of directly and indirectly conditioned space.

Directly Conditioned Space *is an enclosed space that is provided with wood heating, is provided with mechanical heating that has a capacity exceeding 10 Btu/(hr-ft^2), or is provided with mechanical cooling that has a capacity exceeding 5 Btu/(hr-ft^2), unless the space conditioning system is designed and thermostatically controlled to maintain a process environment temperature less than 55°F or to maintain a process environment temperature greater than 90°F for the whole space that the system serves, or unless the space conditioning is designed and controlled to be incapable of operating at* *temperatures above 55 F or incapable of operating at temperatures below 90 F at design conditions.* This definition contains several key ideas central to the *Standards*. First, mechanically heated or mechanically cooled space (discussed below) may be conditioned (i.e., it does not have to be both heated and cooled). Second, it depends on how much heating or cooling is provided to determine if the space is directly conditioned. It is not uncommon for an otherwise unheated space (such as a warehouse) to have a small area with a unit heater, such as a desk on the loading dock. This usually does not make the entire structure a heated space (see also semi-conditioned space). The total quantity of heating provided to the space has to exceed 10 Btu/(hr-ft^2). Similar logic applies to a mechanical cooling system; if it provides more than 5 Btu/(hr-ft^2), it means the space is directly conditioned. Third, it matters at what temperature the space is controlled. Many spaces, such as refrigerated warehouses, are conditioned but are deliberately kept at very hot or cold temperatures. The space conditioning is not for human comfort but to serve the needs of some process, such as preventing vegetables from spoiling. If the space conditioning system is specifically designed and operated to maintain a temperature that is not within the range of 55°F through 90°F and is thermostatically controlled not to operate within this temperature range, then the space is *not* directly conditioned. Note that these spaces are treated like semi-conditioned spaces and therefore must meet the lighting requirements.

Note: the reference to wood heating in the above *Standards* definition of **Directly Conditioned Space** pertains to low-rise residential buildings only (§100(a)3.B). Nonresidential building with wood heat are semi-conditioned.

Example 2-1–
Direct Heating

Question

If a space were 1,000 ft^2 , how large would the heating system have to be to make the space directly conditioned?

Answer

The heating system would have to be larger than 10 Btu/(hr-ft^2) x 1,000 ft^2 = 10,000 Btu/hr output to meet the definition of directly conditioned space.

Example 2-2–
Direct Heating

Question

A water treatment plant has a heating system installed to prevent pipes from freezing. The heating system exceeds 10 Btu/(hr-ft^2) and operates to keep the space temperature from falling below 50 F. Is this plant directly conditioned?

Answer

Not if the heating system is sized to meet the building load at 50 F and is thermostatically controlled to prevent operating temperatures above 50 F. The definition of directly conditioned space excludes spaces that have space conditioning designed and controlled to be incapable of operating at temperatures above 55°F at design conditions. Under these conditions, the space is not directly conditioned.

Example 2-3–
Direct Cooling

Question

A manufacturing facility will have space cooling to keep the temperature from exceeding 90 F. If the thermostat will not allow cooling below 90 F is this facility directly conditioned?

Answer

No, this facility is not directly conditioned. The definition of directly conditioned space excludes spaces where the space conditioning system is designed and controlled to be incapable of operating at temperatures below 90°F at design conditions.

Enclosed Space *is space that is substantially surrounded by solid surfaces.* Spaces that are not enclosed are spaces that are open to the outdoors, such as covered walkways, parking structures that are open or have fenced mechanical enclosures.

Entire Building *is the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all existing conditioned and unconditioned space within the structure.* This definition affects lighting compliance within the complete building method.

Habitable Story *is a story that contains space in which humans may work or live in reasonable comfort, and that has at least 50 percent of its volume above grade.* This definition is important in distinguishing between high-rise and low-rise residential buildings, which are covered by different *Standards* and are described in separate *Manuals*. Basement floors with more than 50 percent of their volume below grade are not counted as habitable stories regardless of their actual use. In buildings on sloping ground, the calculation of volume below grade can become cumbersome, but for most buildings it will be obvious whether the floor is at least 50 percent above grade.

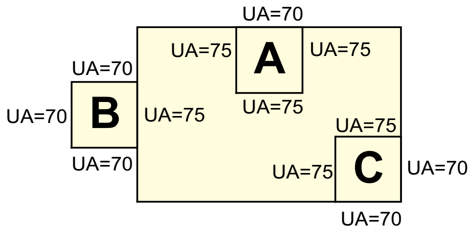
Indirectly Conditioned Space *is enclosed space including, but not limited to, unconditioned volume in atria, that (1) is not directly conditioned space; and (2) either (a) has an area-weighted heat transfer coefficient to directly conditioned space exceeding that to the outdoors or to unconditioned space, or, (b) is a space through which air from directly conditioned spaces is transferred at a rate exceeding 3 air changes per hour.* This definition is important because the *Standards* treat indirectly conditioned space the same as conditioned space; in other words, indirectly conditioned spaces must meet the requirements of the *Standards*. As a guide, professional judgment should be exercised when determining whether a space is *indirectly conditioned*, especially as relates to door placement in the space. When an enclosed space that is not directly conditioned has openings only into a conditioned space, it should be considered indirectly conditioned. Likewise, when an enclosed space that is not directly conditioned has openings only to the outdoors, it should be considered to be unconditioned. When enclosed spaces that are not directly conditioned have openings both to the outdoors and to conditioned spaces, an evaluation of relative heat transfer and air change rate (UxA - see Example 2-4) should be used to determine the status of the space. A typical example of an indirectly conditioned space might be the stairwell of a high-rise office building. The first part of the definition is that it not be directly conditioned. This is not uncommon in stairwells. The second part of the definition is that it be provided with space conditioning energy from a space that is directly conditioned. This can be done one of two ways. The first is by conduction heat transfer. If heat is transferred in from directly conditioned space (e.g., through the walls of the stairwell) faster than it is transferred out to the unconditioned surroundings, then the space is considered to be indirectly conditioned (see Example 2-4). The second way is for the space to be ventilated with air from directly conditioned spaces. For example, if exhaust hoods draw air through a kitchen from the dining room at a rate exceeding three air changes per hour, then the kitchen will be considered indirectly conditioned space.

Example 2-4– Indirectly Conditioned Space (by conduction)

Question

The accompanying sketch shows a building with three unconditioned spaces (none has a direct source of mechanical heating or cooling). The air transfer rate from the adjacent conditioned spaces is less than 3 air changes per hour. The area weighted heat transfer coefficients of the walls (UA) are shown on the sketch. The roof/ceiling area weighted heat transfer coefficients (UA) for each of the three unconditioned spaces is 90 Btu/Hr - °F.

Are any of these spaces indirectly conditioned?



Answer

Because the air change rate is low, we evaluate each space on the basis of heat transfer coefficients through the walls and roof. It is further assumed that the floors are adiabatic. Therefore, the heat transfer will be proportional to the area weighted heat transfer coefficients of the walls and roof/ceilings.

SPACE A: The area weighted heat transfer coefficient to directly conditioned space is 3 x (75 Btu/Hr-°F) = 225 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is 70 Btu/Hr-°F + 90 Btu/Hr-°F = 160 Btu/Hr-°F. Since the heat transfer coefficient from Space A to the conditioned space is greater than heat transfer coefficient from Space A to outside, Space A is considered indirectly conditioned.

SPACE B: The area weighted heat transfer coefficient to directly conditioned space is 75 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (3 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 300 Btu/Hr-°F. Since the heat transfer coefficient from Space B to the conditioned space is less than the heat transfer coefficient from Space B to outside, Space B is considered unconditioned.

SPACE C: The area weighted heat transfer coefficient to directly conditioned space is (2 x 75 Btu/Hr-°F = 150 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (2 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 230 Btu/Hr-°F. Since the heat transfer coefficient from Space C to the conditioned space is less than the heat transfer coefficient from Space C to outside, Space C is considered unconditioned.

Mechanical Cooling *is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space. In nonresidential, high-rise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling (see also "directly conditioned space").* For buildings covered by this *Manual,* evaporative cooling is not considered mechanical cooling. This means, for example, that a warehouse with only evaporative coolers does not meet the definition of mechanical cooling. Nonresidential buildings with evaporate cooling are semi-conditioned spaces.

Mechanical Heating *is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy from depletable sources to directly condition the space.* If the only source of the heat is a nondepletable source, then the system is not considered mechanical heating. Nondepletable sources would include solar collectors, geothermal sources, and heat recovered from a process, such as refrigeration chillers.

Newly Conditioned Space *is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semi-conditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition.*

Process *is an activity or treatment that is not related to the space conditioning, lighting, service water heating, or ventilating of a building as it relates to human occupancy.*

Semi-Conditioned Space *is an enclosed nonresidential space that is provided with wood heating, cooling by direct or indirect evaporation of water, mechanical heating that* *has a capacity of 10 Btu/(hr ft^2) or less, mechanical cooling that has a capacity of 5 Btu/(hr ft^2) or less, or is maintained for a process environment as set forth in the definition of DIRECTLY CONDITIONED SPACE* (also see definition of 'process' above). Buildings in which the mechanical heating and cooling system are serving a process load (such as refrigerated warehouses), are designated a semi-conditioned spaces. Buildings that are semi-conditioned *must* meet the lighting requirements of the *Standards* (see Chapter 5). No mechanical or envelope compliance is required as long as the building is maintained as a semi-conditioned space.

Space Conditioning System *is a system that provides either collectively or individually heating, ventilating, or cooling within or associated with conditioned spaces in a building.* The *Standards* apply to conditioned space, and they govern the space conditioning systems that provide the conditioning for those spaces.

Unconditioned Space *is enclosed space within a building that is not directly conditioned, indirectly conditioned or semi-conditioned space.* Unconditioned space is not covered by the *Standards.*

A. Occupancies

High-Rise Residential *is a building, other than a hotel/motel; of occupancy group R-1 with four or more habitable stories.* UBC Occupancy Group R-1 includes apartment houses, convents and monasteries (accommodating more than 10 persons). (See definition of Unconditioned Space above). If a building has four or more habitable stories, any residential occupancy in the building is considered high-rise residential, regardless of the number of stories that are residential.

Example 2-5– High-Rise Residential

Question

A four-story building has one floor retail, two floors are offices and the fourth floor is residential (as defined in the UBC). Is the residential space high-rise or low-rise?

Answer

It is a high-rise residential space. Even though there is only one floor of residential occupancy, the building has four habitable stories, making it a high-rise building.

Hotel/Motel *is a building or buildings incorporating six or more guest rooms or a lobby serving six or more guest rooms, where the guest rooms are intended or designed to be used, or which are used, rented, or hired out to be occupied, or which are occupied for sleeping purposes by guests, and all conditioned spaces within the same building envelope. Hotel/motel also includes all conditioned spaces that are (1) on the same property as the hotel/motel, (2) served by the same central HVAC system as the hotel/motel, and (3) integrally related to the functioning of the hotel/motel as such, including, but not limited to, exhibition facilities, meeting and conference facilities, food service facilities, lobbies and laundries.* A key part of this definition is that the hotel/motel includes all spaces within the same building envelope as the lobby or the guest rooms. This is because hotel/motel buildings are generally multi-purpose facilities. They may include such diverse spaces as restaurants, auditoriums, retail stores, offices, kitchens, laundries and swimming pools. All are treated as hotel/motel spaces.

This concept extends to other buildings associated with the hotel/motel that pass the three tests:

- Same property
- Same central HVAC system
- Integrally related to the hotel/motel

Refer also to Section 6.2 for a complete discussion of hotel/motel compliance issues.

Mixed Occupancies The *Standards* apply to mixed occupancies in the same way they apply to single occupancy buildings. The low-rise residential *Standards* apply to applicable occupancies; the nonresidential *Standards* apply to appropriate occupancies. If these two types occur in the same building, the building must be treated as two separate buildings for purposes of energy compliance, with each part meeting its applicable requirements. An exception provides that if one occupancy makes up 90% of the building, the entire building may comply with the provisions of the dominant occupancy. The mandatory measures for the actual occupancy will apply. This subject is discussed and illustrated in greater detail in Section 2.2.2F.

Live-Work buildings are a special case, as they combine residential and nonresidential uses within individual units. Live-Work buildings are required to meet the applicable Low-rise or High-rise Residential Standards, due to the fact that these buildings operate (and therefore are conditioned) 24 hours per day. Lighting in designated workspaces is required to show compliance with the Nonresidential prescriptive lighting requirements (§146). Low-rise residential Standards apply to live/work units that are part of a building with no more than three habitable stories. Note that the loft space in a unit with high ceilings is not counted as a separate story.

Other Occupancy Definitions: There are over 35 additional occupancy definitions in the *Standards*. They are used primarily to assign lighting area categories. Refer to the Glossary, Appendix G, for these definitions (found alphabetically under “Occupancy Type)”.

2.2.2 Application Scenarios

This section illustrates the use of the application rules in typical building situations.

A. Unconditioned Space

Unconditioned space is neither directly nor indirectly nor semi-conditioned, as defined in the previous section. Unconditioned space is not subject to the *Energy Efficiency Standards*. Some typical examples of spaces that may be unconditioned:

- Parking structures
- Automotive workshops
- Covered entry courts or walkways
- Outdoor dining areas
- Greenhouses
- Loading docks
- Mechanical/electrical equipment rooms

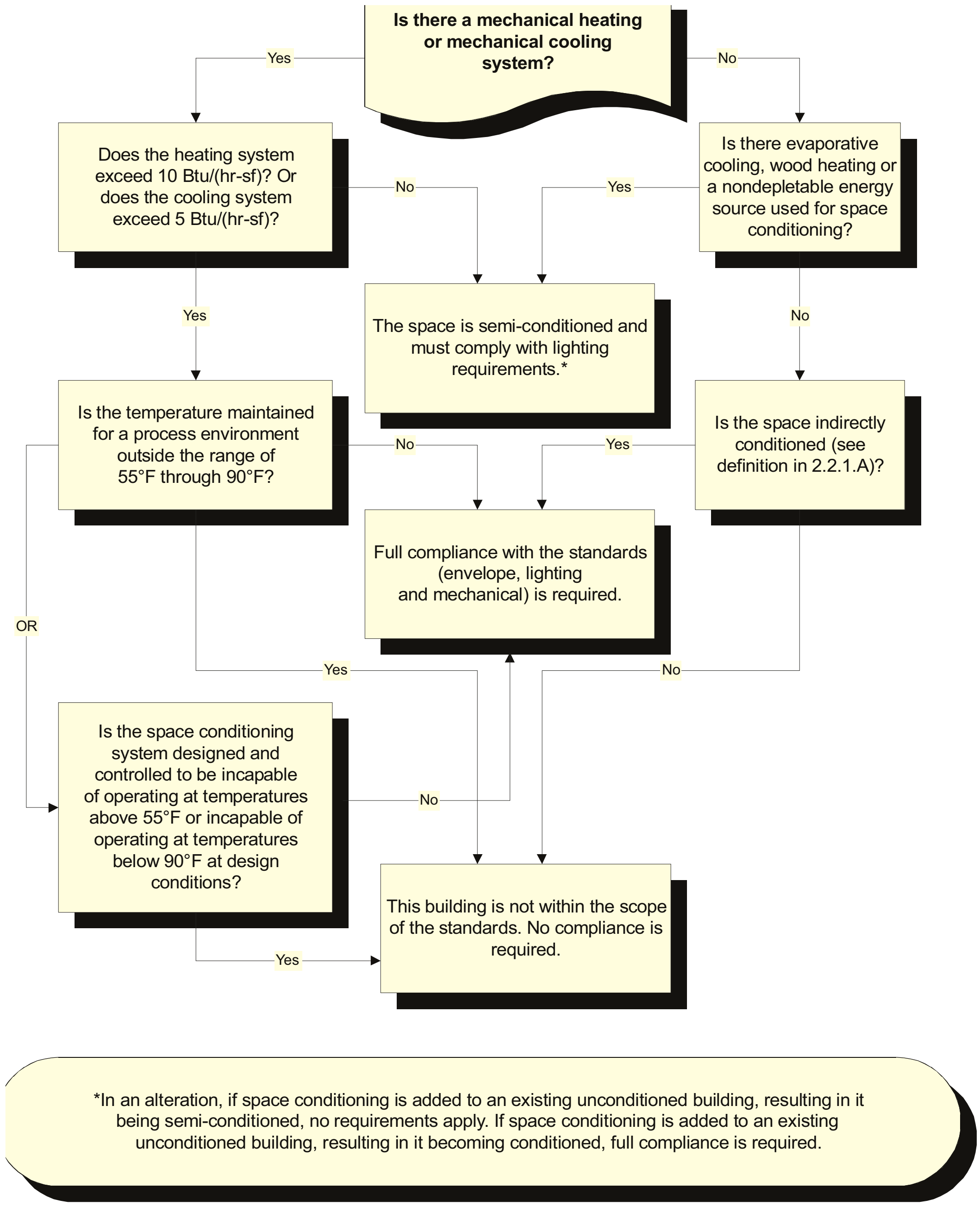
Keep in mind that these kinds of spaces are not always unconditioned. The specifics of each case must be determined. See the flowchart in Figure 2-1 to determine whether a space is unconditioned, conditioned, or semi-conditioned.

B. Newly Conditioned Space

While unconditioned buildings do not have to comply with the *Standards,* it is not simple to change an unconditioned building to a conditioned building.

When previously unconditioned space becomes conditioned, the space is then considered an “addition” and all the building’s components must then comply as if it were a new building (see Section 2.2.2E below and *Standards* §149(a).) If conditioning an existing building results in a space that is semi-conditioned, the *Standards* do not apply.

Figure 2-1– Type of Conditioned Space and Scope of Compliance



This situation has potentially significant construction and cost implications. For example, if an unconditioned warehouse is upgraded with a heating system thus becoming conditioned space, the building envelope must comply with the current envelope requirements and the lighting system must be brought into conformance with the current lighting requirements, including mandatory wiring and switching. If the envelope has large windows, it is conceivable that some would have to be eliminated or replaced with more efficient windows. If the lighting system is inefficient, fixtures might have to be removed and new, more efficient fixtures installed.

This requirement can cause difficulty when an owner of a building seeks exemption from complying with the *Standards* by erecting a shell with no plans to condition it. For example, the owner of an office building obtains a permit for the structure and envelope, but wishes to leave the space conditioning and lighting improvements to the tenants. If that owner claims unconditioned status for that building, the owner does not have to demonstrate compliance with the envelope requirements of the *Standards.* As soon as the tenant applies for a permit to install the HVAC equipment, however, the envelope and any existing lighting in the shell must then be brought into full compliance. (This is the only circumstance when systems, other than those subject to the current permit application, fall under the *Standards.*) If the building was initially designed in a way that makes this envelope compliance difficult, the building envelope may require expensive alterations to bring it into compliance. A similar situation could occur with the lighting system if it is installed in the "unconditioned" building.

Many building departments require the owner to sign an affidavit at the time of the initial building permit for the shell, acknowledging the potential difficulties of future envelope or lighting compliance. For a discussion of the compliance procedures associated with this practice, refer to Sections 3.3, 4.3 and 5.3.

To minimize *Standards* compliance difficulties, the recommended practice is to demonstrate energy compliance at the time the envelope is built, and to demonstrate compliance for the lighting systems even when lighting systems are installed in unconditioned spaces.

C. New Construction in Existing Buildings

Alterations, tenant improvements, and repairs are new construction in an existing building. For example, the base building has been constructed, but the individual tenant spaces have not been completed. Tenant improvements can include work on the envelope, the mechanical or the lighting systems. Whatever the case, the system or systems being installed are considered to be new construction, and must comply with some or all of the current *Standards*, depending on the extent of the changes (see following sections).

The only circumstance when systems other than those subject to the current permit application come under scrutiny is when the tenant improvement results in the conditioning of previously unconditioned space. Refer to the previous Section 2.2.2 for a complete discussion of this situation.

D. Alterations to Occupied Spaces

Alteration *is any change to a building's water heating system, space conditioning system, lighting system, or envelope that is not an addition.* Alterations or renovations to existing conditioned spaces have their own set of rules for energy compliance. They are covered in a separate section of the *Standards,* §149(b). (Additions are discussed in Section 2.2.2E.)

In summary, the alteration rules are:

1. The *Standards* apply only to those portions of the systems being altered; untouched portions need not comply with the *Standards*.
2. If an envelope or lighting alteration increases the energy use of the altered systems, the alteration must comply with the current *Standards*.

3. Alterations must comply with the mandatory measures for the changed components.
4. New systems in the alteration must comply with the current *Standards*.
5. In an existing semi-conditioned building, altered lighting must meet mandatory measures for the changed lighting component. Alterations that increase the connected lighting load or replace more than 50% of the lighting fixtures must meet current *Standards*.
6. In an existing, unconditioned building where evaporative cooling is added (making the building semi-conditioned) the existing unaltered envelope and lighting do not need to be brought into compliance with current *Standards*.

The effect of these rules is that, in most cases the existing systems (envelope and lighting) set the standard for the altered systems. For example, if the existing lighting system is changed but does not increase the connected lighting load, does not replace more than 50% of fixtures, but meets the applicable mandatory measures, it complies. The same holds true for changes to the envelope: if the overall heat loss or heat gain is not increased and it meets its applicable mandatory measures, then it complies. Mechanical system alterations are governed primarily by the mandatory measures.

The alternative alteration rule is to make changes to the existing building so that the entire building (existing and alteration) complies with the performance approach of the current *Standards*. Keep in mind that, under the performance approach, credit is given only for systems that are actually changed in the current construction process (see Section 6.1 and *Standards* §149(b)). Also see Sections 3.2.5, 4.2.4, and 5.2.6.

Example 2-6– New Window

Question

An owner wants to add more than 50 ft^2 of new glazing in an old building. This will increase the glazing area. How do the *Standards* apply?

Answer

The total area of fenestration (existing and new) should not exceed 40% of the gross exterior wall area (considering only the altered wall of the permitted space).

The new glazing must meet the prescriptive requirements (§143) for the component being altered. This means meeting the glass U-factor, percentage, and shading requirements of the current *Standards*. For example, a building in Climate Zone 9, with a WWR of 15% would require the new glazing to have a U-factor equal to or less than 0.81, and a relative solar heat gain of 0.61 or less (all orientations). In addition, the window must be rated for U-factor and SHGC either with default values and labels or be rated and labeled in accordance with NFRC standards and programs.

Example 2-7– New Lighting Fixture

Question

A building owner wants to change existing lighting fixtures with new ones. Do the *Standards* restrict the change in any way?

Answer

If more than 50% of the fixtures are replaced, in the permitted space (excluding enclosed spaces where no new lighting fixtures are proposed), or the connected load is increased, the *Standards* will treat this as a new lighting system that must comply with §146. Any applicable mandatory requirement affected by the alteration applies, and the mandatory switching requirements would apply to the improved system if the circuiting were altered. Title 20 Appliance Efficiency Regulations requirements for ballasts would also apply. See Section 5.2.1.

Example 2-8– New Interior Partitions

Question

A building owner wants to rearrange some interior partitions and re-position the light fixtures in the affected rooms. Do the energy *Standards* apply to the work?

Answer

Each of the newly arranged rooms must have its own light switches. Since there is no change in the connected lighting load or the exterior envelope, only the mandatory light switching requirements would apply. Refer to Section 5.2.1 for more detail on these requirements.

Example 2-9– Altered Duct Work

Question

A building owner wants to re-arrange some duct work and add some additional fan coils to an existing HVAC system to improve comfort. Do the energy *Standards* apply to the work?

Answer

There would be no change in the load on the system nor any increase in its overall capacity, so the *Standards* would not apply to the central system. Only the duct construction requirements apply to altered ducting (see Section 4.2.1K).

Example 2-10– Chiller Replacement

Question

A building owner wants to replace an existing chiller. No other changes will be made to the HVAC system. Do the *Standards* restrict the change in any way?

Answer

The mandatory efficiency requirements would govern the efficiency of the new chiller (see Section 4.2.1A). The other parts of the system are unchanged and therefore unaffected by the *Standards*.

Example 2-11– Adding a Mezzanine

Question

A building owner has a high ceiling space and wants to build a new mezzanine space within it. There will be no changes to the building envelope or to the central HVAC system. There will be new lighting installed. How do the *Standards* apply?

Answer

Since a mezzanine does not add volume, it is an alteration, not an addition. The existing systems are not affected unless they are altered. The new lighting must comply with all requirements of the *Standards*. The envelope is unchanged, so there are no requirements for it. The mechanical system duct work is simply extended without increase in system capacity, so only the duct construction and insulation requirements apply.

E. Additions

Addition *is any change to a building that increases conditioned floor area and conditioned volume.*

Additions involve either the construction of new, conditioned space and conditioned volume, or the installation of space conditioning in a previously unconditioned space. The mandatory measures, and either the prescriptive or the performance requirements apply. The heating, lighting, envelope, and water heating systems of additions are treated the same as for new buildings. The only exception to this is if the existing systems are simply extended into the addition (*Standards* exception to §149(a)). Refer above to Section 2.2.2B for further discussion of previously unconditioned space.

There are three options for the energy compliance of additions under the *Standards*:

Option 1: Treat the addition as a stand-alone building with adiabatic walls to conditioned space (§149(a)1. and (§149(a)2.B.1.). This option can employ either the prescriptive or the performance approach.

Adiabatic means the common walls are assumed to have no heat transfer between the addition and the adjacent conditioned space, and are ignored entirely.

Option 2: Combine the existing building with the addition (§149(a)2.B.2.). This option only works with the performance approach. It uses the custom budget approach to develop an energy budget for the existing building and a standard version of the addition. These combine into a total building energy budget. The combined building is then modeled as proposed. If it meets the budget, the addition complies. The Standard Design for any alterations to existing lighting and mechanical systems must meet the requirements for altered systems in §149(b).

This option will generally work to ease the energy requirements of the addition only if there are energy improvements to the existing building. It does allow the designer to make a relatively energy inefficient addition comply.

Option 3: The existing structure combined with the addition can be shown to comply as a whole building with all requirements of the current *Standards* for envelope, lighting and mechanical.

Example 2-12– Energy Inefficient Addition

Question

A restaurant adds a greenhouse-style dining area with large areas of glazing. It is directly conditioned space. How can it comply with the *Standards*?

Answer

Because of its large glass area, it will not comply on its own. By making substantial energy improvements to the existing building (lighting, mechanical or envelope), or upgrading the existing building so that the entire building meets the requirements for new construction, it is possible for the combined building to comply. The performance approach would be used to model the combined existing/new building.

F. New Buildings

Speculative Buildings - Known Occupancy

Speculative buildings of known occupancy are commonly built by developers. For example, if a strip shopping center or an office building were built on speculation, the owner would usually know the ultimate occupancy of the space but might not know the actual tenants. For this type of building, the owner could take responsibility for any or all of the major components by simply building and showing energy compliance for the envelope, and leaving the lighting and HVAC improvements to the tenants (or the project could include the other systems as well).

Because compliance may be demonstrated for each component separately, the owner can simply demonstrate that the systems being built meet the *Standards*. The remaining construction and *Standards* compliance work can be dealt with as each tenant obtains building permits for work in their individual spaces (see Section 2.2.2C).

Often, the developer will seek to minimize first cost by delaying compliance and construction of as much of the project as possible. While this can be done under the *Standards,* there are two disadvantages:

1. If all *Standards* compliance is deferred by declaring the building to be unconditioned, the owner needs to understand the potential problems that could arise later when the building is conditioned. Refer to the discussion in Section 2.2.2B above.
2. If only the envelope or lighting systems are shown to comply, the owner loses the opportunity to apply the performance approach to the entire building and so to

make trade-offs between systems to optimize the cost-effectiveness of the design.

Speculative Buildings - Unknown Occupancy

Speculative buildings are often built for which the ultimate occupancy is determined at the time of leasing and not during construction of the building shell. The structure, for example, could eventually be used as an office, a warehouse, a restaurant, or retail space. Because the *Standards* treat these occupancies in a similar fashion, the fact that the ultimate occupancy is unknown is not a significant problem. The major items affected by the ultimate occupancy have to do with lighting and ventilation requirements.

The major problem that can occur with this type of building comes when the owner elects to declare it as an unconditioned building and defer *Standards* compliance until such time as a tenant installs mechanical space conditioning equipment. Refer to Section 2.2.2B for a complete discussion of this problem.

Mixed Use Buildings

Because the *Standards* are different for residential and nonresidential buildings, and because mixed use buildings occasionally include more than one type of occupancy, there is potential for confusion in application. The *Standards* address these circumstances regarding mixed use buildings:

1. **Minor Occupancy** (exception to §100(e)). If the minor occupancy or occupancies occupy less than 10% of the total conditioned floor area, then they may optionally be treated as if they were of the major occupancy. The mandatory measures applicable to the minor occupancy, if different from the major occupancy, would still apply.

2. **Different Nonresidential Occupancies**. When both of these occupancies fall under the nonresidential *Standards*, they would be dealt with together under the same compliance process. Although the occupancies may have different envelope and lighting requirements, these are not so different as to require special compliance procedures.

3. **Hotel/motel and Nonresidential Occupancies.** A hotel/motel with guest rooms, restaurants, sports facilities and other nonresidential occupancies is defined as a hotel/motel occupancy (see Section 2.2.1A and *Standards* §101(b)). The only variance is that the guestroom envelope and lighting and HVAC control requirements are different.

4. **Mixed Low Rise Residential and Nonresidential Occupancies.** These occupancies fall under different sets of *Standards,* they are considered separately. Two compliance submittals must be prepared, each using the calculations and forms of its respective *Standards*.

Example 2-13– Minor Occupancy

Question

A 250,000 ft² high-rise office building includes a small 500 ft² apartment for use by visiting executives. This is clearly a residential occupancy, so is the apartment required to meet the residential requirements of the *Standards*?

Answer

No. It occupies less than 10% of the total conditioned floor area, so it is a minor occupancy and may be treated as part of the office occupancy. Residential mandatory measures apply.

Semi-Conditioned Buildings

Some buildings such as warehouses may fall into the category of a semi-conditioned building (see 2.2.1 to determine if a space is unconditioned or semi-conditioned). The *Standards* require only lighting compliance in buildings that are semi-conditioned.

G. Change of Occupancy

A change of occupancy alone does not require any action under the energy *Standards*. If changes are made to the building, however, then the rules for alterations or additions apply (see Sections 2.2.2D and 2.2.2E).

If the change in occupancy involves converting from a residential to a nonresidential occupancy or vice versa (changes defined by UBC occupancy definitions), then the *Standards* applicable to the new occupancy would govern any alterations made to the building. For example, if a home is converted to law offices, and a new lighting system is installed, the nonresidential lighting requirements would apply. If a new HVAC system is installed, all the nonresidential HVAC requirements, would have to be met.

If no changes are proposed for the building, it is advisable to consider the ventilation requirements of the new occupancy. For example, if a residence is converted to a hair salon, the ventilation rates of the building should be considered. With new sources of indoor pollution, the existing residential ventilation rates would likely not be adequate for the new uses.

H. Repair

A Repair is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. Repairs shall not increase the preexisting energy consumption of the required component, system, or equipment.

3 Building Envelope

3.0 Summary

This chapter discusses the requirements of the Energy Efficiency Standards *(Standards)* as they apply to the building envelope (walls, roofs, floors, windows, skylights, etc.). It addresses common questions asked by building envelope designers, plan checkers and inspectors. Additional information is found in Chapter 2: Scope and Application and Chapter 6: Special Topics.

The Introduction section (3.1) explains the basic envelope compliance approaches and provides a tutorial on many of the concepts necessary for understanding the envelope requirements. The Envelope Design Procedures section (3.2) discusses the requirements of the *Standards* as they concern a designer. The Envelope Plan Check Documents section (3.3) explains the compliance forms and the information, which must be included on the plans by the designer prior to being checked by the building department.

3.1 Introduction

The design of the building envelope is generally the responsibility of an architect, although it may be done by a contractor, an engineer, or some other person. The designer is responsible for making sure that the building envelope complies with the *Standards*. Likewise, the building official is responsible for making sure that the building envelope is designed and built in conformance with the *Standards*. This chapter is written for the designer and the building official, as well as other specialists who participate in the design and construction of the building envelope.

3.1.1 Envelope Compliance Approaches

The envelope requirements contain more than one approach to compliance in order to allow flexibility to accommodate the wide variety of nonresidential buildings. The characteristics, advantages and disadvantages of each method are introduced in this Section. These requirements are in addition to the envelope mandatory measures, which apply regardless of the compliance approach (Section 3.2.1).

A. Prescriptive Approach (§143)

Under the prescriptive approach there are two alternatives for envelope compliance: the Envelope Component Approach and the Overall Envelope Approach.

Envelope Component Approach vs. Overall Envelope Approach

Envelope Component Approach (§143(a)) is the simpler and more direct of the two prescriptive compliance approaches. It consists of a specific requirement for each envelope component: roofs and ceilings, exterior walls, demising walls, external floors and soffits, windows, and skylights.

There are no trade-offs between components. If all the requirements are met, the envelope complies. If even one component does not meet its individual requirement, the envelope does not comply.

Under the Envelope Component Approach, each opaque assembly has to meet a minimum insulation level. Each glazing component has to meet insulating and solar heat gain coefficient (SHGC) values, and there is an upper limit on glazing area. If these requirements are met, the building complies with the *Standards.* See Section 3.2.2 for a more complete discussion of the Envelope Component Approach.

Overall Envelope Approach (§143(b)) treats envelope components as a system. This offers the ability to make trade-offs between envelope components, which is the principal advantage of this approach.

The Overall Envelope Approach uses two measures of envelope performance: the overall heat loss and the overall heat gain. The overall heat loss is a measure of the insulating quality of all the envelope components together, including both opaque and glazing surfaces. The overall heat gain considers insulation, solar heat gain through windows and skylights, and the reflectance of the roof.

The code baseline for both heat gain and heat loss is determined using the insulation and solar heat gain coefficient values from the Envelope Component Approach, and applying them to the envelope surface areas of the proposed building (with some limits on glazing area). The proposed design's overall heat loss and heat gain are calculated based on the installed insulation, fenestration performance, and roof surface properties. If the proposed heat loss and heat gain are no higher than the standard heat loss and heat gain, then the envelope complies. See Section 3.2.3 for a more complete discussion of the Overall Envelope Approach.

B. Performance Approach (§141)

The other option for envelope compliance is the Performance Approach. It may be used for either envelope-only compliance or may include lighting and mechanical system compliance when these systems are permitted at the same time. When the performance approach is used for the envelope only, the computer model deals with the energy efficiency of the entire envelope under both heating and cooling conditions. This means that trade-offs can be made between all envelope components. The computer analysis is much more sophisticated and can account for more subtle energy effects due to surface orientation and hourly changes in the outside temperature. If the envelope compliance is combined with other parts of the building, then more trade-offs can be made, such as increasing envelope efficiency in order to allow more lighting power or a less efficient mechanical system. See Sections 3.2.4 and 6.1 for a more complete discussion of the performance approach.

3.1.2 Basic Envelope Concepts

In order to understand the particulars of each of the compliance approaches, several key definitions and energy concepts must be presented. In addition, before proceeding to the discussion below, the reader should be familiar with the various conditioned space definitions (see Section 2.1.1A).

A. Definitions (§101(b))

Atrium is an opening through two or more floor levels other than enclosed stairways, elevators, hoistways, escalators, plumbing, electrical, air-conditioning, or other equipment which is enclosed space and not defined as a mall. The definition of an atrium is significant because of the skylight area requirements. The key concept is that the atrium is an opening through floor levels, not counting openings needed for equipment. Malls are not considered as atria. The skylight requirements are different when the atrium is over 55 feet high. According to the UBC, an atrium over 55 feet high must have a mechanical ventilation system (particulars defined in the UBC), so the higher skylight allowances for atriums only apply when the ventilation system is required. In questionable cases, the determination of atrium height will be made by the building department, and will follow UBC guidelines.

Cool Roof *is a roofing material with high solar reflectance and high emittance that reduces heat gain through the roof.* To qualify as a cool roof, concrete or tile roofs must have an initial reflectance greater than 0.40 and other roofs must have an initial reflectance greater than 0.70. All cool roofs must have an emittance greater than 0.75. Cool roofs are typically white and have a smooth texture. Commercial roofing products that qualify as cool roofs are either tiles or coatings. Tiles are made of light colored concrete or clay with high reflectance and emittance. Painted metal roofing products are also eligible for cool roof credits (note that the minimum coating thickness requirement does *not* apply to these products). Coatings are applied to single ply or other material to increase the reflectance and emittance of that material. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance assures that when the roof does warm up, its heat can escape through radiation to the sky.

Demising Partitions *are barriers that separate conditioned space from enclosed unconditioned space.* The only difference between an exterior partition and a demising partition is that the demising partition has enclosed unconditioned space on one side, rather than outdoor space. The demising partition could adjoin, for example, an unconditioned warehouse, an enclosed garage, or an unconditioned vestibule. The distinction between exterior and demising walls is made because demising walls have their own requirements and they are not treated the same way as exterior partitions in the energy calculations.

Demising Wall *is a wall that is a demising partition.* A wall is the only case where a demising partition is treated differently from an exterior partition (there are special insulation requirements (§143(a)3 and §118(e)). Glazing area in demising walls is not limited (§141(a) and §143(a)5A).

Display Perimeter *is the length of an exterior wall in a B, F-1 or M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk.* This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to public at large (no obstructions, limits to access, or intervening non-public spaces). The display perimeter is used for a special calculation of window area (§143(a)5A). Demising walls are not counted as part of the display perimeter.

Effective Aperture (See Chapter 5).

Exterior Door *is a door through an exterior partition.* The exterior door area is used only in calculating the gross exterior wall area; there are no R-value, U-factor or area requirements for exterior doors (§143(a)7). Note that if the door has glazing in excess of one-half of the door area, it should be treated as a window or a skylight (depending on slope). See discussion of **Window Area** below for the measurement of glazing area in doors.

Exterior Floor/Soffit *is a horizontal exterior partition, or a horizontal demising partition, under conditioned space.* It is measured using exterior dimensions. Note that the conditioned space can be directly or indirectly conditioned space, and it can adjoin either ambient air or enclosed, unconditioned space. Also note that, unlike the residential *Standards,* slabs-on-grade are not considered exterior floors because they do not separate conditioned space from ambient air or unconditioned space (see discussion of **Exterior Partition** below). A floor over a ventilated crawl space or a parking garage would be an exterior floor. Likewise, in a conditioned attic space, the soffit of an overhanging eave would be considered an exterior floor/soffit because it has unconditioned space below (see Figure 3-1).

Exterior Partition *is an opaque, translucent, or transparent solid barrier that separates conditioned space from ambient air or space that is not enclosed.* It separates conditioned space (including **Indirectly Conditioned Space**) from the outdoors or from spaces that are not enclosed. The terms partition and barrier are used as generic descriptors of any envelope element, including windows, soffits, skylights, metal doors, walls, roofs, etc.

Exterior Roof/Ceiling *is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below, and that is not* *an exterior door or skylight.* This means that the space above the roof or ceiling can be either ambient air or enclosed, unconditioned space. In either case, the envelope requirements for roofs/ceilings apply. An example of an enclosed, unconditioned space would be a ventilated attic or mechanical room. Another would be the ceiling of a conditioned office built within a taller, unconditioned warehouse space (see Figure 3-2).

Exterior Wall *is any wall or element of a wall, or any member or group of members, which defines the exterior boundaries or courts of a building and which has a slope of 60 degrees or greater with the horizontal plane. An exterior wall or partition is not an exterior floor/soffit, exterior door, exterior roof/ceiling, window, skylight, or demising wall.* This leaves only the opaque wall surfaces defined as exterior walls. They separate directly or indirectly conditioned space from the outdoors. Note that they do not include demising walls, which adjoin enclosed unconditioned space.

Exterior Wall Area *is the area of the opaque exterior surface of exterior walls.* It is measured using exterior dimensions. This area does not include windows or doors.

Fenestration or Glazing **Product** (same definition) *is any transparent or translucent material plus any sash, frame, mullions and dividers, in the envelope of a building, including, but not limited to: windows, sliding glass doors, french doors, skylights, curtain walls, garden windows, and other doors with a glazed area of more than one-half of the door area.*

Figure 3-1– Requirements for Floor/Soffit Surfaces

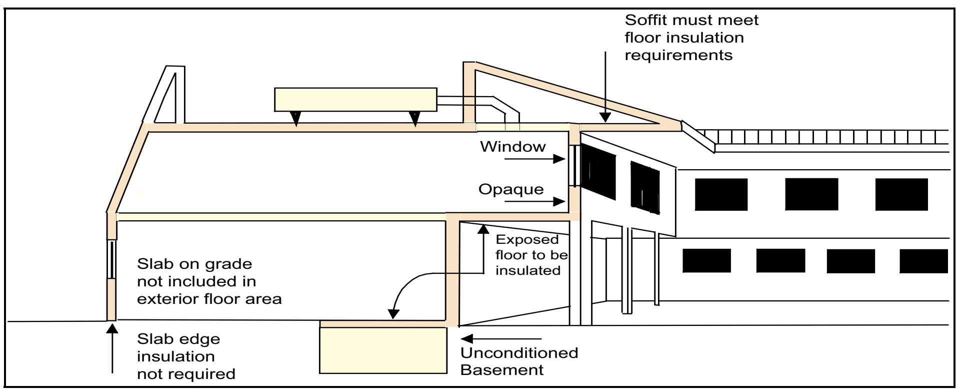
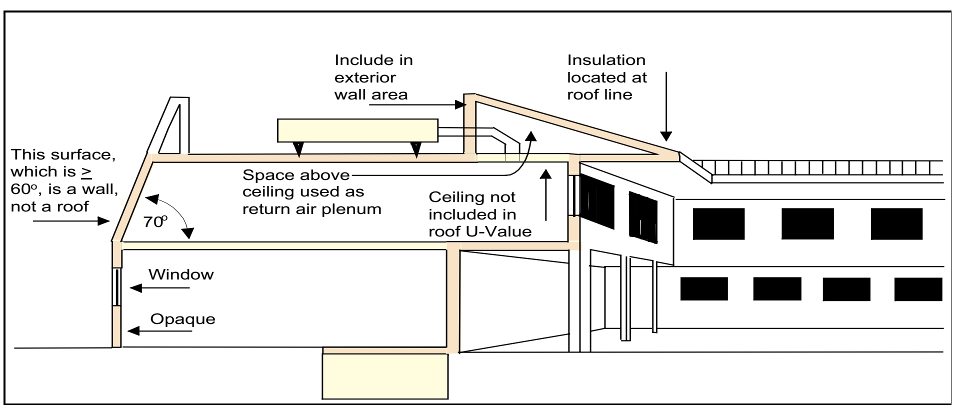


Figure 3-2– Requirements for Roof/Ceiling Surfaces



Field-Fabricated Fenestration Product or Exterior Door *is a fenestration product or exterior door whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked down products, sunspace kits and curtainwalls).* The U-factor and solar heat gain coefficient are determined from the default table (see Table 3-10 and Table 3-12).

Fenestration System *means a collection of fenestration products included in the design of a building. (See "fenestration product").*

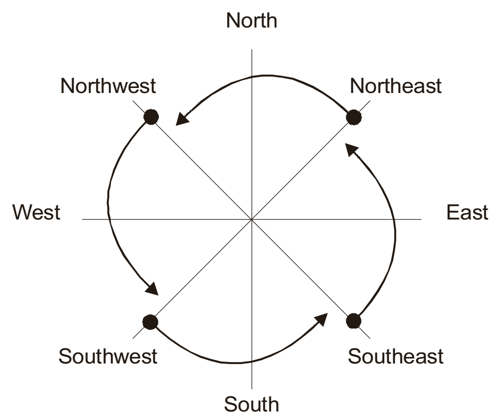
Floor/Soffit Type is a floor/soffit assembly having a specific heat capacity, framing type, and U-factor.

Gross Exterior Roof Area *is the sum of the skylight area and the exterior roof/ceiling area.* Note that this does not include exterior door areas, such as roof hatches. Roof areas are measured using outside dimensions.

Gross Exterior Wall Area *is the sum of the window area, door area, and exterior wall area.* This area is only used to calculate limits on exterior window area.

Orientation (North, East, South and West) see Glossary (Appendix G) definitions of **North-facing, East-facing, etc.** The *Standards* make this distinction because solar heat gain differs by orientation, causing envelope energy flows to vary with orientation. In general, any orientation within 45° of true north, east, south or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-3 indicates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an *east-facing* surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

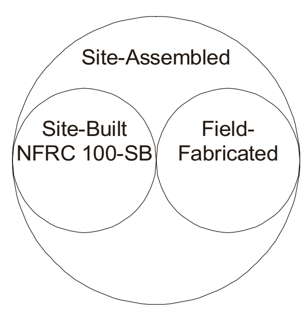
Figure 3-3– Surface Orientations



Relative Solar Heat Gain is the ratio of solar heat gain through a fenestration product (corrected for shading from overhangs) to the incident solar radiation. If there are no overhangs, the RSHG is equal to the SHGC. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted or convected into the space. RSHG is used with the building envelop trade-off method of compliance.

Site-Assembled Fenestration *includes both field-fabricated fenestration and site-built fenestration.* For more information, see the definitions for **Field-Fabricated Fenestration Products** and **Site-Built Fenestration Products**.

Figure 3-4– Fenestration Definitions

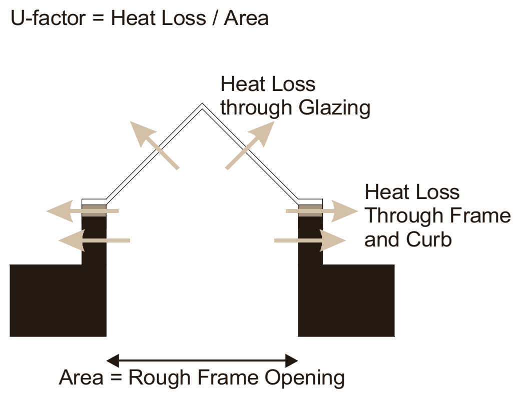


Site-Built Fenestration Products *are fenestration products designed to be field-glazed or field assembled units comprised of specified framing and glazing components. Site-built fenestration is eligible for certification under NFRC 100-SB, and may include both vertical glazing and horizontal glazing.* Examples of site-built products are storefront systems, curtain walls, atrium roof systems and other similar glazing systems. The key distinction between site-built and field-fabricated fenestration is that the latter is not practical to rate since the frames are being constructed at the building site out of raw materials that were not intended to be part of a specific fenestration product.

Skylight *is glazing having a slope less than 60 degrees from the horizontal with conditioned space below*. See discussion of **Slope** below.

Skylight Area *is the area of the surface of a skylight, plus the area of the frame, sash, and mullions.* The rough framed opening is used in the NFRC U-factor ratings procedure; it is also the basis of the default U-factors in Table B-14 in Appendix B. For skylights, the U-factor represents the heat loss per unit of rough framed opening (the denominator). However, the heat loss (the numerator) includes losses through the glazing, the frame, and the curb (see Figure 3-5). Site-built skylights are often used for atrium roofs, malls, and other applications that need large skylights. In such cases the skylight area is the surface area of the glazing and frame/curb (not the area of the rough framed opening), regardless of the geometry of the skylight (i.e., could be flat pyramid, bubble, barrel vault, or other three-dimensional shape).

Figure 3-5– Skylight Area

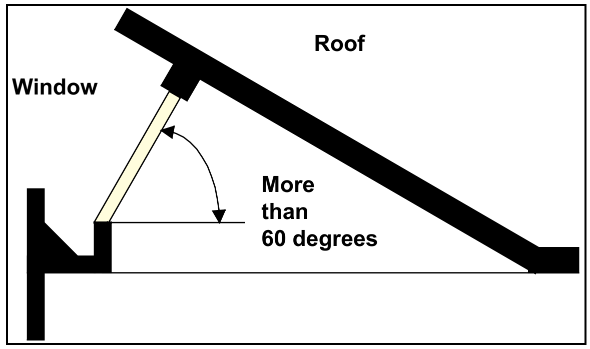


Skylight Type *is a type of skylight assembly having a specific solar heat gain coefficient, and U-factor, whether glass mounted on a curb, glass not mounted on a curb or plastic (assumed to be mounted on a curb).* For determining compliance with the *Standards*, there are three skylight types, glass with curb, glass without curb and plastic with curb.

There are two ways that skylights can be mounted into a roof system, either flush-mounted or curb-mounted. In order to create a positive water flow around them, skylights are often mounted on "curbs" set above the roof plane. These curbs, rising 6 to 12 inches (15 to 30 centimeters) above the roof, create additional heat loss surfaces, right where the warmest air of the building tends to collect.

Slope is used to distinguish between walls and roofs (see **Exterior Roof/Ceiling** definition above). If an exterior partition has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall (see Figure 3-6). This definition extends to fenestration products, including the windows in walls and any skylights in roofs. In Figure 3-6, the window is considered part of the wall because the slope is over 60 degrees. Where the slope less than 60 degrees, the glazing indicated as a window would be a skylight.

Figure 3-6– Slope of a Wall or Window (Roof or Skylight slope is less than 60°)



Solar Heat Gain Coefficient (SHGC) *is the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space.*

Wall Type *is a wall assembly having a specific heat capacity, framing type, and U-factor.*

Well Index (see Section 5.1.1A)

Window *is glazing that is not a skylight.* Note that the window includes any sash, framing, mullions or dividers.

Window Area *is the area of the surface of a window, plus the area of the frame, sash, and mullions.* As a practical matter, window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be a bit larger than the formally defined window area. Use the rough opening area, except for a window in a door. In this case, use the area of the frame that holds the glazing material. For unframed glass doors, use the rough opening of the entire door.

Window Type *is a window assembly having a specific solar heat gain coefficient, relative solar heat gain, and U-factor.*

Window Wall Ratio *is the ratio of the window area to the gross exterior wall area.* Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls. Glazing area in demising walls has no limit and any glazing in demising walls is not counted as part of the exterior wall/window ratio.

B. Insulation R-value (§143(a))

Thermal Resistance (R) is the resistance of a material or building component to the passage of heat in (hr x ft^2 x °F)/Btu.

The R-value of an insulation material is a measure of its thermal resistance. The higher the R-value, the greater the thermal resistance or the better the insulating value of the material. The thicker the material, the greater its R-value. R-values are used in the Envelope Component Method as minimum efficiency requirements. They are also used as part of the calculation of the U-factors of opaque building envelope assemblies. See the following Sections (C through F) on U-factors for more information on these calculations.

Most types of insulating material used in California must be certified by the manufacturer as meeting the California Quality Standards for Insulating Material. See §118 for a more complete description of these requirements.

C. Overall Assembly U-factor (§143(b))

U-factor is the overall coefficient of thermal transmittance of a construction assembly in Btu/(hr x ft^2 x °F), including air film resistance at both surfaces.

The U-factor describes the rate of heat flow through a building surface. The *Standards* specify U-factor limits, which translate into minimum insulation requirements for the envelope. The U-factor tells how many Btu (British thermal units) of heat energy will pass through one square foot of surface area in an hour, for every degree of temperature difference, between inside and outside air. The higher the temperature difference, the more heat will flow. It follows, then, that lower U-factors mean smaller quantities of heat flow, less winter heat loss and less summer heat gain. U-factors are always calculated to three significant digits.

The U-factor calculation varies depending on the composition of the wall, roof, or other assembly under consideration. The variations are discussed in the following sections.

In addition to the insulating properties of the materials that make up a construction assembly, such as a wall, thin layers of air cling to the surface of the assembly. These air films, as they are called, add to the insulating value of the assembly. They are accounted for in the U-factor, and can have a significant effect on envelope compliance, especially for uninsulated assemblies.

Standard air film R-values are to be used for compliance purposes (see the following subsections for discussion of U-factor calculations). The standard values assume that the interior air film is in still air, and that the exterior air film is in a 15 mile per hour breeze, which considerably reduces the thickness and insulating value of the air film. Table 3-1lists the standard air film R-values.

The following subsections describe how the U-factors of various envelope components are calculated. These U-factors are used to demonstrate compliance with the envelope *Standards*.

Note: Weight averaging of assemblies requires a U-factor. R-values cannot be weight averaged.

D. Wood Frame U-factors (§141(c)4.B)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.* Wood-framing is common in smaller nonresidential buildings, and is known by such names as wall stud, roof rafters and floor joists. Wood framing uses small dimension lumber as the structural elements, typically spaced on 16 inch or 24 inch centers. The cavities between the framing members typically are filled with insulation.

Table 3-1 - Standard Air Film R-values

	Wall	Roof Flat [2]	Roof 45 Angle [3]	Floor
Air Films [1]				
Inside	0.68	0.61	0.62	0.92
Outside	0.17	0.17	0.17	0.17
Air Spaces [4]				
0.5 inch	0.77	0.73	0.86	0.77
0.75 inch	0.84	0.75	0.81	0.85
1.5 inch	0.87	0.77	0.80	0.94
3.5 inch [5]	0.85	0.80	0.82	1.00

NOTE: Values from ASHRAE Handbook of Fundamentals, 1993 edition, Chapter 22, Tables 1 & 2.

[1] Assumes a non-reflective surface emittance of 0.90 and winter heat flow direction.

[2] Use the “Flat” roof R-values for roof angles between horizontal and 22 degrees.

[3] Use the 45 degree roof R-values for roof angles between 23 and 60 degrees.

[4]Assumes mean temperature of 90 degrees Fahrenheit, temperature difference of 10 degrees Fahrenheit, surfac

[5] Use these R-values for air spaces greater than or equal to 3.5 inches, such as attics.

Any time a typical wood-frame assembly is used, the U-factors listed in Table B-2 (see Appendix B) can be used (a portion of Table B-2 is included as Table 3-1). Table B-2 provides a wide range of typical wood-framed assemblies.

To use Table B-2, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, determine the R-value of the layer of insulated sheathing (such as rigid foam insulation board) attached to the assembly and select the row of the table showing the U-factor of the assembly. Use the "zero" R-value if there is no insulated sheathing. Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate. These default U-factors must be used for compliance purposes, unless calculations are submitted for each assembly.

Likewise, if the assembly is not included in the table, or if the assembly is a framed floor, ceiling, or soffit, the U-factor must be calculated using the parallel path method, in which case the applicant must submit calculations using form ENV-3 (see Section 3.3.4 thru 3.3.5).

Table 3-2 - Wood Framed Assembly U-factors (excerpt from Table B-2, Appendix B)

Framing Type and Spacing	Framing / Cavity R-value	Insulating Sheathing R-value	Wood Wall U-factor
Wood 2x4 @ 16 in. o.c.	11	5	0.064
		7	0.056
		8.7	0.051
	13	0	0.088
		4	0.063
		5	0.059
		7	0.052
		8.7	0.048
	15	0	0.081

Parallel Path Method. Wood framed assembly U-factors are calculated using the parallel path method (see ENV-3 Wood Framed Assembly). This method takes account of the fact that heat flows at a different rate through the solid wood framing portion of the surface than through the insulated cavity portion. The U-factor developed by the method is essentially an area-weighted average of the U-factors of the frame and cavity areas.

The parallel path method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). For compliance purposes, the parallel path method calculation is done for each wood-framed assembly using the ENV-3 form. Refer to Section 3.3.6 for a step-by-step explanation of this calculation and the form. Because the parallel path method weights the U-factors of the framing and the cavity areas, a key number in the calculation is the *framing percentage.* This number describes the percentage of the surface area that is occupied by framing; the rest is occupied by cavity and insulation. In order to simplify the calculation and to avoid confusion, the *Energy Commission* has adopted common framing percentages, found below in Table 3-1.

Table 3-1 - Wood Framing Percentage

Assembly Type	*Framing Spacing*	*Framing Percentage*
Walls	16" o.c.	15%
	24" o.c.	12%
Floors	16" o.c.	10%
	24" o.c.	7%
Roofs	16" o.c.	10%
	24" o.c.	7%

Source: 1993 ASHRAE Handbook of Fundamentals, Chapter 22

E. Metal Frame U-factors (§141(c)4.C)

Framed Partition or Assembly *is a partition or assembly constructed using separate structural members spaced not more than 32 inches on center.* Metal framing, typically using steel studs, rafters or joists made of rolled shapes of light gauge steel, is common in non-combustible construction. The framing techniques are similar to those for wood framing; small dimension structural members are typically placed on 16 inch or 24 inch centers, and the cavities between the framing members are filled with insulation. This method does not apply when the framing spacing is 32 inches or more.

Metal-framed assemblies have greater heat transfer than wood-framed assemblies, of similar construction. This is because the steel material is an effective heat conductor. Heat flows rapidly through the framing members, bypassing the cavity insulation. The net result is substantial reduction in the effectiveness of the insulation.

To account for this effect, the zone method is used for determining the U-factor of a metal-framed assembly instead of the parallel path method. This method is described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22 (see Appendix B). A hand calculation using the zone method is elaborate, and is not recommended for use without training.

Other alternatives to performing zone method calculations include the use of ENV-3 for Metal Framed Assemblies, default table (Table 3-2), and a computer program were developed by the *Energy Commission* to determine the U-factors of construction assemblies, including those with metal framing (see Appendix B).

Table 3-2 is an excerpt from Table B-2, the Wall Assembly U-factor Table found in Appendix B, which provides U-factors for a wide range of typical metal-framed wall assemblies. They were calculated using the zone method. These values may be used for compliance purposes, unless the applicant submits calculations for each assembly separately (using form ENV-3 Metal Frame; see Section 3.3.4). Interpolating or extrapolating values in this table is prohibited.

To use this table, identify the appropriate type and spacing of the framing. Next, locate the R-value of the cavity insulation. Finally, use the R-value of the layer of insulated sheathing attached to the assembly and select the row of the table showing the U-factor of the assembly. Use "zero" R-value if there is no insulated sheathing.

Table 3-2 - Metal Framed Assembly U-factors (excerpt from Table B-2)

Framing Type And Spacing	Framed Wall Assembly U-Values		
2x4 @ 16" o.c.	Framing Cavity R-Factor	Insulated Sheathing R-Factor	Metal Wall U-Factor
	R-11	0.0	0.202
		4.0	0.112
		5.0	0.101
		7.0	0.084
		8.7	0.073

Note that *insulated sheathing* does not include ordinary building materials such as plywood or stucco; it is rigid board material designed to be used as insulation. Examples of this type of insulation are polystyrene and polyisocyanurate.

If the value in Table B-2 is not used, or if the assembly is a metal-framed floor, ceiling or soffit, the U-factor may be calculated using the metal framing factors found in Table 3-3 (see Appendix B, Table B-3). Using the ENV-3 Metal Framed Assembly form described more fully in Section 3.3.4, multiply the values in this table by the sum of R-values of all layers including air films, excluding any insulated sheathing. Add the insulated sheathing R-value, if any, to obtain the total assembly R-value. Using this value, calculate the U-factor.

Table 3-3 - Metal Framing Factors

Metal Framing Factors*			
Stud Spacing	Stud Depth	Insulation R-Value	Framing Factor
16" o.c.	4"	R-7	0.522
		R-11	0.403
		R-13	0.362
		R-15	0.328
	6"	R-19	0.325
		R-21	0.300
		R-22	0.287
		R-25	0.263
24" o.c.	4"	R-7	0.577
		R-11	0.458
		R-13	0.415
		R-15	0.379
	6"	R-19	0.375
		R-21	0.348
		R-22	0.335
		R-25	0.308

R-value calculation for Exterior Wall Assemblies with Metal Studs, July 19, 1990, Staff Draft Docket 90-CON-1.

*Correction to metal framing factors applies to the entire assembly including: interior air films, interior surfaces, cavity/insulation, exterior surfaces, and exterior air films.

F. Masonry U-factors (§141(c)4.E)

Masonry wall assemblies are typically built using concrete masonry units (block), or with various clay products (brick or tile). They also include solid masonry or concrete assemblies, such as tilt-up concrete walls. The heat flow across these walls can be complex because of the voids in the wall, the solid material bridges through the wall, and the reinforcing and grouting of some of the voids for structural reasons.

The recommended procedure for determining masonry wall U-factors are to use the tables of values provided in this *Manual* in Tables B-4 through B-6 (see Appendix B). Alternatively, it is permissible to use either the method of transverse isothermal planes described in the *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 22, or the method described in *Energy Calculations and Data*, published by the Concrete Masonry Association of California and Nevada, 1986.

A simplified version of the latter method was used to develop Table B-4, excerpted in Table 3-4. This table lists various typical hollow unit masonry units by nominal wall thickness (12", 10", etc.), and by material type. For example, NW CMU refers to normal weight concrete masonry units (concrete blocks). The table also provides for the three typical core treatments: solid grout and two types of partially grouted core treatments. The ungrouted cells in partially grouted walls are either empty or filled with perlite insulation. The table gives the U-factor for the wall, including interior and exterior air films. It also provides the total R-value and the heat capacity (HC) (see Section 3.1.2G for more on heat capacity). The use of these numbers in determining the U-factor of complex masonry assemblies is explained in Section 3.3.5 (ENV-3: Proposed Masonry Wall Assembly).

Table 3-4 - Properties of Hollow Unit Masonry Walls (excerpt from Table B-4)

Type			Core Treatment		
			Solid	Partly Grouted with Ungrouted Cells	
			Grout	Empty	Insulated
12"	LW CMU	U	0.51	0.43	0.30
		Rw	2.0	2.3	3.3
		HC	23	14.8	14.8
	MW CMU	U	0.54	0.46	0.33
		Rw	1.9	2.2	3.0
		HC	23.9	15.6	15.6
	NW CMU	U	0.57	0.49	0.36
		Rw	1.8	2.0	2.8
		HC	24.8	16.5	16.5

Table B-5 in Appendix B is used to find the values for solid masonry assemblies not made up of hollow masonry units (e.g. poured concrete), and is excerpted in Table 3-5.

Table 3-5 Properties of Solid Unit Masonry and Solid Concrete Walls (excerpt from Table B-5)

Type		Layer Thickness, inches			
		3	4	5	6
LW CMU	U	na	0.71	0.64	na
	Rw	na	1.4	1.6	na
	HC	na	7.00	8.75	na
MW CMU	U	na	0.76	0.70	na
	Rw	na	1.3	1.4	na
	HC	na	7.67	9.58	na
NW CMU	U	0.89	0.82	0.76	na
	Rw	1.1	1.2	1.3	na
	HC	6.25	8.33	10.42	na
Clay Brick	U	0.80	0.72	0.66	na
	Rw	1.3	1.4	1.5	na
	HC	6.30	8.40	10.43	na
Concrete	U	0.96	0.91	0.86	0.82
	Rw	1.0	1.1	1.2	1.2
	HC	7.20	9.60	12.00	14.40

G. Heat Capacity

Heat Capacity (HC) of an assembly is the amount of heat necessary to uniformly raise the temperature of the assembly one degree F. It is calculated as the sum of the average thickness times the density times the specific heat for each component, and is expressed in Btu per square foot per degree F. Heat capacity is a measure of the thermal mass of an assembly. It is used to determine the prescriptive envelope requirements for walls and floors.

Table 3-6 - Effective R-Values for Interior Insulation Layers on Structural Mass Walls (excerpt from Table B-6)

Type		Furring space R-value without framing effects										
Actual Thickness	Frame	0	1	2	3							
Any	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10
0.5”	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	na	na
0.75”	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	na	na
1.0”	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	na	na

For a single layer, homogeneous wall or floor, such as poured concrete walls with no applied finish materials, heat capacity can be calculated by multiplying the weight of the wall (pounds per square foot) times the specific heat. For instance, a 6 inch concrete wall (specific heat = 0.20 Btu/lb-°F) with a weight of 70 pounds per square foot would have an HC of 70 x 0.20 or 14 Btu/ft^2-°F. To calculate the wall weight from the density (pounds per cubic foot), multiply the density by the wall thickness (inches) and then divide by 12 (inches), which gives the wall weight in pounds per square foot.

For assemblies made up of many layers, the HC may be calculated separately for each layer and summed. The Proposed Construction Assembly, form ENV-3, includes a procedure for calculating HC in simple layered assemblies (see Section 3.3.6)

Table 3-7 lists the thermal properties of typical, thermally massive construction materials. See Appendix B, Table B-1, for a more thorough listing of the thermal characteristics of materials.

The HC of unit masonry walls, such as those made of concrete block or brick, are too complicated to calculate by this method. Appendix B, Materials Reference includes Tables B-4 and B-5 with HCs calculated for a large variety of masonry wall assemblies. See Section 3.1.2F for an introduction to these tables.

Table 3-7 - Thermal Mass Properties

Matter	Conductivity (Btu/hr-ft-oF)	Density (Lbs/cf)	Specific Heat (Btu/b-oF)
Adobe	0.33	120	0.20
Heavy Concrete	0.98	140	0.20
Lightweight Concrete	0.36	85	0.20
Gypsum	0.09	50	0.26
Masonry Veneer	6.62	127	0.20
Masonry Infill	0.44	120	0.20
Concrete Masonry Unit	0.59	105	0.20
Grouted Concrete Masonry Unit	1.00	134	0.20
Stucco	0.47	105	0.20
Tile in Mortar	0.67	120	0.20
Solid Wood (fir)	0.07	32	0.33
ASHRAE Handbook of Fundamentals, Table 4, Chapter 22			

H. Cool Roofs (§118, §10-113)

***Cool Roof** is a roofing material with high solar reflectance and high emittance that reduces heat gain through the roof.* The term “cool roof” refers to the outer layer or exterior surface of the roof. As the term implies, the temperature of a cool roof is lower on hot sunny days than a conventional roof, reducing cooling loads and the energy required to provide air conditioning.

4 5 6 7 8 9 10

The reflectance criterion is obvious: dark surfaces absorb sunlight and become hot and light colored surfaces reflect sunlight and stay cooler. However, the emittance criterion is also important. Emittance relates to the ability of heat to escape from a hot surface. Surfaces with a low emittance (usually shiny metallic surfaces) trap heat in the building structure, while surfaces with a high emittance allow it to escape through radiation to the cool night sky.

There are several ways to achieve the light color and high emittance required to qualify as a cool roof. One of the best methods is to use a single ply roofing membrane with the surface properties an integral part of the material. Another way to achieve a cool roof is to apply a coating to the surface of a conventional roof membrane, such as modified bitumen or a mineral top sheet. There are a number of qualifying liquid products, including elastomeric coatings and white acrylic coatings. Coatings must be applied with a minimum thickness of 20 mils across the entire surface and meet minimum standards for durability.

There are no mandatory requirements to install cool roofs, but credits are offered through the overall envelope approach and the whole building performance method. To qualify for the cool roof credits, the exterior roof surface must have an initial reflectance greater than 0.70 (0.40 for concrete or clay tile) and an emittance of 0.75 or greater.

Before January 1, 2003, the eligibility criteria may be verified through manufacturer's published performance data. After January 1, 2003, qualifying roofing materials must be certified and labeled by the Cool Roof Rating Council (CRRC). The certification and labeling requirements for cool roofs are specified in §10-113. The following text from the standard describes the test methods and criteria for the various classes of cool roofs.

Concrete tile (as defined in ASTM C55-99) and clay tile (as defined in ASTM C1167-96) roofing products shall have a minimum initial total solar reflectance of 0.40 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

All other roofing products shall have a minimum initial total solar reflectance of 0.70 when tested in accordance with ASTM E903 or E1918, and a minimum thermal emittance of 0.75 when tested in accordance with ASTM E408.

Liquid applied roofing products shall be applied at a minimum dry mil thickness of 20 mils across the entire roof surface, and meet the minimum performance requirements of ASTM D6083-97 when tested in accordance with ASTM D6083-97 for the following key properties: initial tensile strength, initial elongation, elongation after 1000 hours, accelerated weathering, permeance, and accelerated weathering.

Table 3-8 - Cool Roof Performance Criteria

Required Criteria	Concrete Tile	All Other Cool Roofs
Emittance	0.4	0.7
Reflectance	0.75	0.75
Material thickness	Not Applicable	20 mils for liquid applied. Not applicable for other roofing materials
Labeling		
Before 1/1/2003	Through manufacturer's Published performance data.	Through manufacturer's Published performance data.
After 1/1/2003	Certified and labeled by the Cool Roof Rating Council	Certified and labeled by the Cool Roof Rating Council
Compliance Credit Method	Performance and Overall Envelope	Performance and Overall Envelope

I. Fenestration U-factors (§141(c)4.D)

The U-factor for a fenestration product describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-factor includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions (there also may be spacers, sealants and other elements that affect heat conduction). For skylights mounted on a curb, the total heat flow considered in determining the U-factor includes losses through the curb, as well as the frame, glazing and other components. For projecting windows (greenhouse windows), the total heat flow includes the side panels, base and roof of the projecting window assembly. However, the area used to determine the U-factor for skylights and projecting windows is the rough framed opening. Using the rough framed opening eases the process of making load calculations and verifying compliance since the rough framed opening is easier to calculate than the actual surface area of the projecting window or skylight.

The Definitions (§101(b)) section of this chapter lists many of the terms and product characteristics that relate to fenestration U-factors. In particular see definitions for window, skylight, window area, skylight area, site-assembled fenestration, site-built fenestration and field-fabricated fenestration.

Table 3-9 shows acceptable procedures for determining fenestration U-factors for four classes of fenestration: manufactured windows, skylights, site-built fenestration and field-fabricated fenestration.

Table 3-9 - Acceptable Methods for Determining U-factors

	Fenestration Class			
			Site-Assembled	
U-factor Determination Method	Manufactured Windows	Skylights	Site-Built Fenestration	Field-Fabricated Fenestration
NFRC 100 (1997)				
NFRC 100-SB				
Default U-factors from Table 3-10 (same as *Standard* Table 1-D)				
Default U-factors from Appendix B, Table B-14 same as ACM Appendix I Table I-1		(Note 1)	(Note 2)	(Note 2)

Note 1: The default U-factors from Appendix B (Table B-14) may also be used for site-assembled horizontal glazing.

Note 2: The default U-factors from Appendix B (Table B-14) may only be used for site-assembled fenestration in buildings having less than 100,000 ft² of floor area or less than 10,000 ft² of site-assembled vertical fenestration area.

The preferred methods for determining fenestration U-factor are those in NFRC 100 (1997) for manufactured windows and NFRC 100-SB for site-built fenestration. These methods may be used for all classes of fenestration, although typically they are not practical for field-fabricated fenestration. For manufactured windows, the default U-factors in Table 3-10 below (*Standard* Table 1-D) must be used if NFRC determined U-factors are not available. This table can also be used for site-assembled fenestration (see Table 3-9 above). These U-factors represent the high side of the range of possible values, thereby encouraging designers to obtain ratings through NFRC procedures, when they are available.

NFRC U-factors are less likely to be available for skylights than they are for windows, where limited test data can be extended through calculations. Typically, acrylic skylights must be individually tested. When NFRC data is not available, two other SHGC methods are available. One method is to use values from Table 3-12 (*Standard* Table 1-E from

§116). The values are on the high sided and do not account for special coatings and other technologies that may be part of a proposed fenestration product. The default U-factors for site-built fenestration in buildings less than 100,000 square feet of conditioned floor area or with less than 10,000 square feet of vertical site built glazing, are also listed in Appendix B, Table B-14.

The recommended method for determining the U-factor of site-built fenestration systems (curtain walls and storefront systems) is to use the NFRC 100-SB (site-built) procedure. This requires that a sample of the curtain wall assembly be assembled and tested in an NFRC approved laboratory. The NFRC procedure is optional for a building that has less than 100,000 ft^2 of conditioned floor area or has less than 10,000 ft^2 of site-built vertical fenestration area. If the building has less than 100,000 ft^2 of floor area or has less than 10,000 ft^2 of site-assembled vertical glazing area, then U-factors used for compliance for site-assembled products may instead be selected from Table B-14 of Appendix B of this *Manual* or Table 3-10.

Note: Manufactured fenestration in buildings under 100,000 ft^2 must still either be rated and labeled in accordance with NFRC procedures or labeled using Table 3-10 (§116, *Standard* Table 1-D) values.

For buildings larger than 100,000 ft^2 of floor area and with 10,000 ft^2 of site-built vertical fenestration area, there are two compliance choices with regard to U-factor and labeling of site-built fenestration.

Go through the NFRC process and get a label certificate. This is the option described in §10-111(a)1C.

Use the default tables from Table 3-10 (or §116, *Standard* Table 1-D). This is option §10-111(a)1A. This option results in very conservative U-factors.

Field-fabricated fenestration is site-assembled fenestration that does not qualify as site-built fenestration. It includes windows where wood frames are constructed from raw materials at the building site, salvaged windows and other similar products. For this class of fenestration product, U-factors may be taken from Table 3-10 below, from Appendix B, Table B-14, or by using NFRC 100-SB to determine a specific value for the field fabricated product.

Table 3-10 - Default Fenestration Product U-factors

Frame Type [Note 1]	Product Type	Single Pane U-Factor	Double Pane U-factor [Note 2]
Metal	Operable	1.28	0.87
	Fixed	1.19	0.72
	Greenhouse/Garden Window	2.26	1.40
	Doors	1.25	0.85
	Skylight	1.72	0.94
Metal, Thermal Break	Operable	n. a.	0.71
	Fixed	n. a.	0.60
	Greenhouse/Garden Window	n. a.	1.12
	Doors	n. a.	0.64
	Skylight	n. a.	0.80
Non-Metal	Operable	0.99	0.60
	Fixed	1.04	0.57
	Doors	0.99	0.55
	Greenhouse/Garden Window	1.94	1.06
	Skylight	1.47	0.68

Note 1: Metal includes any field-fabricated product with metal cladding. Non-metal framed manufactured fenestration products with metal cladding must add 0.04 to the listed u-factor. Non-metal frame types can include metal fasteners, hardware, and door thresholds. Thermal break product design characteristics are:

a. The material used as the thermal break must have a thermal conductivity   3.6 Btu-in./hr-ft²-°F,

b. The thermal break must produce a gap of   0.210 in.,

c. All metal members of the fenestration product exposed to interior and exterior air must incorporate a thermal break meeting the criteria in (a) and (b) above. In addition, the fenestration product must be clearly labeled by the manufacturer that it qualifies as a thermally broken product in accordance with §116.

Note 2: For all dual glazed fenestration products, adjust the listed U-factors as follows:

a. Subtract 0.05 for spacers of 7/16” or wider.

b. Subtract 0.05 for products certified by the manufacturer as low-E glazing.

c. Add 0.05 for products with dividers between panes if spacer is less than 7/16” wide.

d. Add 0.05 to any product with true divided lite (dividers through the panes).

J. Solar Heat Gain Coefficient (§141(c)5)

The solar heat gain coefficient (SHGC) is a measure of the quantity of solar heat entering a window or skylight; the lower the SHGC, the lower the amount of solar heat gains. A low SHGC reduces solar heat gains, thereby reducing the amount of air conditioning energy needed to maintain comfort in the building. A low SHGC may also increase the amount of heat needed to maintain comfort in the winter. The technical definition of SHGC is the ratio of solar energy entering the window (or fenestration product) to the amount that is incident on the outside of the window. As with the U-factor, frame type as well as the type of glazing affects SHGC.

There are four acceptable methods for determining SHGC for use with the *Standards* (see Table 3-11). The preferred methods are to use one of the two NFRC procedures: NFRC 200 for manufactured fenestration and skylights or NFRC 100-SB for site-built fenestration including skylights. NFRC 100-SB is a method that is available for site-built fenestration products where the glazing is in only one plane.

The third method is to use the SHGC Default Table 3-12, which is the same as Table 1-E in the Standards. These values are on the high side and do not account for special coatings and other technologies that may be part of a proposed fenestration product.

The fourth method is to use the Alternative Calculation Method for SHGC Compliance in Appendix B, Table B-12. This method allows, under limited conditions, the use of two different equations, one for site-assembled fenestration and the other for manufactured fenestration. Each equation calculates an overall SHGC for the fenestration ($SHGC_{fen}$) assuming a default framing factor and using the center-of-glass SHGC value ($SHGC_c$) for the glazing from the manufacturer’s literature. The equation for site-assembled fenestration can only be used for site-built or field-fabricated fenestration for buildings that are less than 100,000 square feet of conditioned floor area or have less than 10,000 square feet of site-assembled vertical fenestration.

Note: The method outlined in Appendix B (Table B-12) to determine the SHGC for site-assembled fenestration products uses an equation that adapts data available for center-of-glass. The Equation $SHGC_{fen} = 0.11 + 0.81 \times SHGCc$ cannot **be used for** site-assembled vertical glazing in buildings with (a) 100,000 ft^2 or more of conditioned floor area and (b) 10,000 ft^2 or more of vertical fenestration area **and after October 1, 2002 cannot be used for manufactured products regardless of the size of the building**. $SHGC_C$ data is commonly available from glass manufacturers and glazing fabricators. The data is provided in product catalogs and on their websites. Manufacturer’s data for glazing materials should be **determined in a manner** consistent with NFRC 200.

Buildings that are greater than 100,000 square feet of conditioned floor area or have more than 10,000 square feet of site-assembled vertical fenestration cannot use the site-assembled equation. The equation for manufactured fenestration can only be used for manufactured fenestration in buildings for which the building permit is applied for prior to October 1, 2002. After October 1, 2002 the manufactured fenestration equation can no longer be used.

Table 3-11 - Methods for Determining SHGC

	Fenestration Class		
SHGC Determination Method	Manufactured Windows	Skylights	Site-Assembled
			Site-Built Fenestration
NFRC 200 (1995)			Field-Fabricated Fenestration
NFRC 100-SB			
Default SHGC values from Table 3-12 (same as *Standard* Table 1-E)			
SHGC alternative procedure from Appendix B, Table B-12 (see equations from Table B-12 below)			
$SHGC_{fen} = 0.08 + 0.86 \times SHGCc$			(Note 1)
Prior to October 1, 2002, $SHGC_{fen} = 0.11 + 0.81 \times SHGCc$	(Note 2)		(Note 1)
Note 1: The SHGC procedure defined in Appendix B of this *Manual (Table B-12) may* only be used for site-assembled fenestration in buildings that are less than 100,000 ft^2 of floor area or have less than 10,000 ft^2 of site-assembled vertical fenestration area.			
Note 2: For permits submitted prior to October 1, 2002, manufactured fenestration products that do not have SHGC values determined using NFRC 200 may calculate the SHGC using the equation shown in the first column of this table, where $SHGC_c$ is the SHGC for the center of glass alone, and $SHGC_{fen}$ is the SHGC for the complete fenestration product including glass and frame. Beginning October 1, 2002, manufactured fenestration products must be certified for overall SHGC in accordance with NFRC 200 procedures or use Default SHGC values from Table 3-12.			

Table 3-12 - Default Solar Heat Gain Coefficients

Frame Type	Product	Glazing	Single Pane	Double Pane
Metal	Operable	Clear	0.80	0.70
	Fixed	Clear	0.83	0.73
	Operable	Tinted	0.67	0.59
	Fixed	Tinted	0.68	0.60
Metal, Thermal Break	Operable	Clear	0.72	0.63
	Fixed	Clear	0.78	0.69
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.65	0.57
Non- Metal	Operable	Clear	0.74	0.65
	Fixed	Clear	0.76	0.67
	Operable	Tinted	0.60	0.53
	Fixed	Tinted	0.63	0.55

Windows are not allowed credit for any interior shading such as draperies or blinds. Only exterior shading devices (i.e. shade screens) permanently attached to the building, or a structural component of the building, can be modeled for performance standards compliance. Manually operable shading devices cannot be modeled. Only overhangs can be credited using the Relative Solar Heat Gain procedure (see Subsection N below) for prescriptive compliance.

Visible light transmission (VLT) is a property of glazing materials that has a varying relationship to SHGC. VLT is the ratio of light that passes through the glazing material to the light that is incident on the outside of the glazing. Light is the portion of solar energy that is visible to the human eye. VLT is an important characteristic of glazing materials, because it affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low VLT have little daylighting benefit and views appear gloomy, even on bright days. The ideal glazing material would have a high VLT and a low SHGC. Such a glazing material would allow solar radiation in the visible spectrum to pass while blocking radiation in the infrared and ultraviolet spectrums. Materials that have this quality are labeled "spectrally selective" and have a VLT that is 20% or so higher than the SHGC. Higher VLT can result in energy savings in lighting systems. See Section 5.2.1.

K. Site-built Fenestration (§116, §10-111)

Manufactured fenestration products arrive at the construction site as a unit, and the manufacturer is able to assume the burden of testing and labeling. However, with site-assembled fenestration, multiple parties are responsible. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and sometimes, the method of assembly. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks, etc. A glazing manufacturer provides the glazing units, cut to size and fabricated as insulated glass (IG) units. The glazing manufacturer is responsible for tempering or heat strengthening, the tint of the glass, any special coatings, the spacers and sealants. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site and is responsible for many quality aspects. Glazed wall systems are often custom designed for buildings, making it more difficult to predetermine the performance of the system as a whole, as compared to manufactured units.

The National Fenestration Rating Council (NFRC) adopted NFRC 100-SB (Site-Built) in 2000 to address the special needs of site-built fenestration products. The NFRC procedures are recommended for all site-built fenestration systems, but are mandatory for large construction projects unless the high range default values from Table 3-10and Table 3-12 are used. Large construction projects are those that have 100,000 ft² or more of floor area and 10,000 ft² or more of site-built vertical fenestration. The requirement is intended to apply to large office buildings and other nonresidential buildings with large curtain wall systems. The cost for testing and labeling site-built glazing systems varies with the size of the project. Many of the costs are fixed, so the cost per square foot is lower in larger projects. This is the primary initially rationale for requiring NFRC testing and labeling only for larger construction projects.

One of the parties (architect, glazing contractor, extrusion manufacturer, insulated glass unit (IG) fabricator, or glass manufacturer) must take responsibility for testing and labeling of the site-built fenestration system under the NFRC 100-SB procedure. The responsible party must obtain a NFRC license and establish a relationship with a NFRC certified simulation laboratory, a NFRC certified testing laboratory and a NFRC certified independent agent (IA). For more information on the licensing process, refer to the NFRC web site at http://www.nfrc.org/.

The responsible party must work with the glazing or curtain wall supplier(s) to carry out the following steps:

Arrange for a NFRC accredited simulation laboratory to evaluate and determine the thermal performance of each product line.

Make an arrangement with a NFRC accredited testing laboratory to conduct a validation test on each product line.

Forward copies of the simulation and test reports to a NFRC accredited independent agent (IA) for review.

The NFRC certified independent agent (IA) then issues an NFRC Label Certificate that is kept on file in the general contractor's construction office and posted on-site for review by the building code inspector. The NFRC Label Certificate provides the same function as the temporary label that is required for manufactured fenestration products.

It is typical for the glazing contractor to assume responsibility for the team and to coordinate the certification and labeling process. A common procedure is for the design team to include language in the contract documents that require that the general contractor be responsible; the general contractor typically assigns this responsibility to the glazing contractor. Once the glazing contractor has established a relationship with an independent agent (IA), a simulation laboratory and a testing laboratory, the process works well, and it should not delay either the design or construction process.

It is not necessary to complete the NFRC testing and labeling prior to filing the building permit application and completing the compliance documentation. However, plan examiners should verify that the fenestration performance shown in the contract documents (plans and specifications) and used in the compliance calculations is "reasonable" and achievable. This requires some judgment and knowledge on the part of the plans examiner. Generally, designers will know the type of glass that they plan to use and whether or not the frame has a thermal break or is thermally improved. This information is adequate to consult the default values in Appendix B, Table B-14. If the values used for compliance are within 5% of the values from Appendix B, Table B-14, then the values may be considered reasonable for plan check. If the compliance values are outside the 5% range, the plans examiner should request information from the designers to justify the proposed values. It may be necessary for the design team to consult with NFRC simulation laboratories to determine what technologies might be required to achieve the specified level of performance.

After the construction contract is awarded, the glazing contractor assumes responsibility for getting the simulations and tests made and for obtaining the NFRC Label Certificate. The IA issues a separate label certificate for each "product line". Each label certificate has the same information as the NFRC temporary label for manufactured products, but includes other information specific to the project such as the name of the glazing manufacturer, the extrusion contractor, the places in the building where the product line is used and other details. The label certificate remains on file in the construction office for the building inspector to view. After construction is complete, the label certificate should be filed in the building office with the as-built drawings and other operations and maintenance data. This will give building managers the information needed for repairs or replacements. Those who use Field-fabricated fenestration do not usually follow the NFRC 100-SB process and instead use default values published by the Commission. See Table 3-1and Table 3-12

Example 3-1– NFRC Testing of Site-Built Fenestration

Question

A designer is using a U-factor of 0.57 for compliance with a curtain wall system. The glazing system uses two lites of 1/4 inch glass with a low-e coating on the second surface. The air gap is 1/2 inch. A standard metal frame is proposed for the curtain wall system. Is 0.57 a reasonable U-factor for compliance and can it reasonably be achieved by the glazing contractor through the NFRC process for site-built fenestration?

Answer

The default U-factor for this glazing combination from Appendix B (Table B-14) is 0.59. The proposed factor of 0.57 is within 5% and should be considered reasonable.

L. Product Line

Product[1] – One of the components of a product line that may have different glass types, different edge of glass characteristics, true or simulated dividers within the glass, or different gas fills.

Product Line[2] – General group of fenestration products that have a similar frame and operating characteristics. Products that are constructed from the same frame material and designs, but differ only in operating characteristics (e.g. a vertical slider and horizontal slider of the same construction) may be in the same product line. Minor changes to hardware to accommodate higher/lower loads and stresses do not necessarily constitute a different product line.

A product line[3] is a given series of fenestration products with the same operator type that differ only in:

1. Size
2. Center-of-glass and edge-of-glass characteristics such as glazing types, glazing coatings, gas-fills, gap widths, use of dividers, use of spacers;
3. Opening/non opening configurations, e.g., XO vs XOX

   Where an “X “denotes an operating panel/sash

   An “O” denotes a fixed or non-operating panel/sash

   Combinations of X’s and O’s denote the appropriate combinations of operating and non-operating panels
4. Minor changes to accommodate smaller/larger glazing unit widths;
5. Minor changes to operating hardware to accommodate higher/lower loads and stresses (including the use of reinforcing in vinyl framed fenestration products);
6. Frame or sash changes where one component is replaced by another component of the same physical shape with a thermal conductivity that does not differ by more than a factor of 10; and

[1] NFRC Certified Products Directory, Ninth edition – December 1999

[2] NFRC Certified Products Directory, Ninth edition – December 1999

[3] NFRC 100 Combined: Procedures for Determining Fenestration Product U-factors – 2000 Edition

7. Interior/exterior appendage added to the main web of the frame that are not exposed after product installation, i.e., nailing fins.

A product line is thus defined by an operator type and a set of basic frame profiles. For each frame/sash element, a base profile must be defined. Frame/sash profiles which differ from these base profiles are part of the same product line as long as the differences are limited to lengthening, shortening, expanding, or deleting specific elements of the base profile (typically incorporated into the product line for different installations). Such differences in the base profile constitute different individual products within the product line. Material changes where the conductivity changes by more than a factor of 10 are not part of the same product line except for the addition of cladding materials applied to the base profile.

Multipurpose fenestration products incorporating nearly identical frame/sash base profiles can be classified and rated as one product line. The products shall be classified in separate groups by operator type within the product line.

Clad products and unclad products can be incorporated into one product line if and only if the cladding system represents a minor change to the frame/sash base profile. The clad and unclad products would be separate individual products within the product line.

Multiple assemblies sometimes referred to as combination or composite windows, including more than one operator type, (e.g., a vertical slider over an awning) and multiple assemblies of the same operator type need not be rated in combination. Each operator type may be evaluated separately.

Non-rectangular fenestration products shall be rated as though they are rectangular fenestration products. Identify all the frame cross sections of the non-rectangular fenestration product. Find or develop a product line with the same frame cross sections as the non-rectangular fenestration product, and choose the rectangular size closest to residential and nonresidential for simulation and testing. If there are no rectangular sizes available in those ranges, a non-rectangular fenestration product with the same frame cross sections, and the closest possible total area can be used for simulation or testing.

M. Fenestration Labeling (§10-111 and 116)

The Administrative Regulations (§10-111) and the *Standards* (§116) require that fenestration products have labels that list the U-factor, the solar heat gain coefficient (SHGC), and the methods used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage. The air leakage requirements are specified in §116 and limit the infiltration rate to 0.3 cfm/ft² for most products.

Each Manufactured fenestration product must have a clearly visible temporary label attached to it, which is not to be removed before inspection by the enforcement agency. For rating and labeling manufactured fenestration products, the manufacturer has two choices for U-factor and, until October 1, 2002, three choices for SHGC. First, the manufacturer can choose to have the fenestration product rated and labeled in accordance with the NFRC Rating Procedure (NFRC 100 for U-factors and NFRC 200 for SHGC). If the manufactured fenestration product is rated using the NFRC Rating Procedure, it must also be permanently labeled in accordance with NFRC procedures. Second, if the manufacturer can choose to use Default values from Table 3-10 for U-factors and Table 3-12 for SHGC. If Default values are used, the manufacturer must attach a temporary label meeting specific requirements (permanent labels are not required). Figure 3-7 shows a sample Default temporary label. Although there is no exact format for the Default temporary label, it must be clearly visible, large enough for the building department field inspectors to easily read it, and include all information required by the regulations. The suggested label size is 4 inches X 4 inches. The label shall have the words “CEC Default U-factor” followed by the correct value for that fenestration product from Table 3-10 and the words “CEC Default SHGC” followed by the correct value from Table 3-12. The U-factor and SHGC Default values should be large enough to be visible from 4 feet. If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criterion, upon which the default value is based, is met. This can be done by placing the term "Meets Thermal-Break Default Criteria" on the temporary label. Note 2 of Table 3-10, the Default U-factor table, provide for positive or negative adjustments to the U-factors in the table for specific fenestration products. For example, products with low-E glazing or air gaps between panes greater than 7/16 inch are adjusted to lower U-factors and products with true divided lites or metal cladding are adjusted to raise U-factors. These adjustments must be included in the U-factor shown on the temporary label. The special features that cause these adjustments should be identified on the label. The manufacturer may also include the VLT factor from manufacturer's data. This factor is important to determine whether daylit area credit may be taken in conjunction with daylighting controls.

For site-built fenestration systems, a label certificate takes the place of both the temporary and permanent label.

Figure 3-7 – Sample Default Temporary Label

CEC Default Label	**XYZ MANUFACTURING Co.**
Key Features:	**Double Pane** **Operable** **Metal, Thermal Break** **Air space 7/16" or greater** **Tinted**
CEC Default **U-factor** **0.66**	**CEC Default** **SHGC** **0.53**
Manufacturer certifies that this Fenestration Product meets the air infiltration requirements of §116 (a) 1 and the thermal-break default criteria of §116 (a) 2, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.	

For site-assembled fenestration products, a label certificate can take the place of the temporary label (permanent labels are not required). For site-built fenestration, NFRC Label Certificates result from ratings through the NFRC 100-SB procedures. For site-assembled fenestration products, which are not rated through the 100-SB procedures, a Default Label Certificate can be provided by the person (e.g., architect, glazing contractor, extrusion manufacturer, IG fabricator or glass manufacturer) taking responsibility for fenestration compliance. Figure 3-8 is a sample CEC Default Label Certificate when using default values from Table 3-10 and Table 3-12, and Figure 3-9 is a sample of the CEC Alternate Default Label Certificate when using default values from Appendix B, Tables B-12 and B-14. A separate Default Label Certificate should be completed for each product line that results in a different U-factor and SHGC. The Default Label Certificate should state the amount of this product line throughout the project, the locations in the project where the product line is installed, and the pages in the drawings and fenestration schedule, which show this product line. The Default Label

Certificate should clearly identify the appropriate table or equation that is used to determine the Default U-factor and SHGC, and the frame type, product type and glazing type that corresponds to the appropriate table and if applicable the center of glass $SHGC_c$ used in calculating the $SHGC_{fen}$. Manufacturer's documentation of these product characteristics must also be attached to the plans. The Default Label Certificate also should contain the words "Meets Thermal-Break Default Criteria" if the product claims the default U-factor for a thermal-break product. The Default Label Certificate also should identify any special features that cause adjustments to raise or lower the default U-factor as specified by the Default U-factor table. The Default Label Certificate may also include the VLT factor to determine whether daylit area credit may be taken in conjunction with daylighting controls. The person taking responsibility for fenestration compliance for the project can choose to attach Default Temporary Labels to each fenestration product as described in the previous paragraph instead of providing Default Label Certificates for each product line. A CEC Alternate Default Label Certificate is acceptable documentation of the information specified in Appendix B, Tables B-12 and B-14 for Field-fabricated fenestration.

Example 3-2– NFRC Testing of Site-Built Fenestration

Question

A 150,000 ft² "big box" retail store has 2,000 ft² of site-built vertical fenestration located at the entrance. The fenestration system consists of two lights of clear 1/4 inch mm glass separated by a 1/2 inch air gap. An aluminum storefront framing system is used, without a thermal break. What are the acceptable methods for determining the fenestration U-factor and SHGC? What are the labeling requirements?

Answer

The site-built fenestration does not have to be rated through the NFRC 100-SB procedures since the total area of vertical site-assembled fenestration is less then 10,000 ft². Also, permanent labels are not required.

The U-factor may be selected from Table B-14 in Appendix B. This table is also contained in Appendix I of the ACM Approval Manual. The U-factor for the specified product is 0.73, which is taken from the first column of the table for double glass with a ½ in. air gap (roughly 12 mm).

The SHGC for the center of the glass is known from manufacturers data and is 0.70. The SHGC for the fenestration product (including the frame) is 0.68 as determined using the following equation:

$$\begin{aligned} SHGCfen &= 0.08 + 0.86 \times SHGCc \\ &= 0.08 + 0.86 \times 0.70 \\ &= 0.68 \end{aligned}$$

A Default Label Certificate should be completed for this fenestration unless the responsible party chooses to attach Default Temporary Labels to each fenestration product throughout the building.

Figure 3-8 – CEC Default U-Factor and SHGC Label Certificate

U-FACTOR AND SHGCLABEL CERTIFICATE FORM

PROJECT INFORMATION

PROJECT NAME: **RIVER CITY OFFICE**	DATE: **August 1, 2001**
PROJECT ADDRESS: **321 North 5th St. Sacramento, CA 95814**	

CEC DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE
(Use only for Site-Assembled Fenestration Product Lines)

Method 1 in this Default Certificate may be used for site-assembled vertical glazing installed in all non-residential buildings.

U-factors and SHGC are derived from the California Energy Commission Fenestration Default U-factors and SHGC Default Table based on data reported below.

U-factor = 0.71
SHGC = 0.73

This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)

Total Number of units for this product line:	2	Total square footage of this product line:	480
Elevation drawing page:	E-3	Fenestration (window & door) schedule page:	E-4, E-6
Location(s) on building: (enter appropriate orientation(s))	South, East, West and North	Total Fenestration Area (ft²) on project:	960

❑ **Method 1** - **DEFAULT FENESTRATION U-FACTOR AND SHGC FROM TABLES 3-18 AND 3-12 OF THE NONRESIDENTIAL MANUAL FOR COMPLIANCE WITH THE 2001 ENERGY EFFICIENCY STANDARDS**

Frame Type	☒ Metal	❑ Metal Thermal Break (or Structural Glazing)			❑ Nonmetal
U-factor Table 3-18 Product Type	❑ Operable	☒ Fixed	❑ Greenhouse, Garden Window	❑ Door	❑ Skylight
Glazing Type	❑ Single Pane	☒ Double Pane	**Default U-factor =**	0.72	(If no adjustment, insert value in above gray box next to U-factor)
SHGC Table 3-12 Product Type	❑ Operable	☒ Fixed			
SHGC Table 3-12 Glazing Tint	☒ Clear	❑ Tint	**Default SHGC =**	0.73	(Insert default value in above gray box next to SHGC)

U-Factor Adjustment (See Table 3-18, Footnote 2)

- ☒ Subtract 0.05 for spacers of 7/16 inch or wider
- ☒ Subtract 0.05 for products certified by the manufacturer as low-E glazing
- ❑ Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide
- ❑ Add 0.05 for products with true divided lite (dividers through the panes)

U-Factor Adjustment = 0.72 – 0.05 – 0.05 = **0.71** (If applicable insert adjustment result in above gray box next to U-factor)

PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:

Contact Person: **Joe Glassguy**		
Company name and address: **453 Venice Way**		
Phone: **916-555-5555**	Fax:	Signature: *Joe Glassguy*

Figure 3-9 – CEC Alternate Default U-Factor and SHGC Label Certificate

ALTERNATIVE DEFAULT U-FACTOR and SHGC LABEL CERTIFICATE

PROJECT INFORMATION

PROJECT NAME: **RIVER CITY OFFICE**	DATE: **August 1, 2001**
PROJECT ADDRESS: **3212 North 5th St. Sacramento, CA 95814**	

CEC ALTERNATIVE DEFAULT U-FACTOR AND SHGC LABEL CERTIFICATE (Use only for Site-Assembled Fenestration Product Lines)

U-factors and SHGC are derived from the California Energy Commission Fenestration Alternative Default U-factors and SHGC Equations based on data reported below.

U-factor = 0.66
SHGC = 0.42

Method 2 Alternative Default Certificate shall not be used for site-assembled vertical glazing installed in buildings with 100,000 square feet or more of conditioned floor area and 10,000 square feet or more of vertical glazing.

This Fenestration Product Line meets the air infiltration requirements of Section 116(a) 1, 2001 California Energy Efficiency Standards for Residential and Nonresidential Buildings.

PRODUCT LINE INFORMATION (Complete a separate Default Label Certificate for each fenestration product line in the project)

Total Number of units for this product line:	2	Total square footage of this product line:	480
Elevation drawing page:	E-3	Fenestration (window & door) schedule page:	E-4, E-6
Location(s) on building: (Enter appropriate orientation(s))	South, East, West and North	Total Fenestration Area (ft²) on project:	960

❑ **Method 2** – DEFAULT FENESTRATION U-FACTOR AND SHGC FROM APPENDIX B, TABLE B-14 AND MANUFACTURER'S DOCUMENTATION

Product Type	X Glazed Wall Systems ❑ Skylight with Curb ❑ Skylight without Curb
Frame Type	X Aluminum ❑ Aluminum Metal Thermal Break ❑ Wood/Vinyl ❑ Reinforced Vinyl Aluminum Clad Wood ❑ Structural Glazing
Glazing Type, Glazing Thickness	❑ Single ⅛" Glass ❑ Single ⅛" Acrylic/polycarb ❑ Single ¼" Acrylic/polycarb X Double Glass ❑ Triple Glazing ❑ Quadruple Glazing
Coating Emissivity	❑ 0.05 ❑ 0.10 ❑ 0.20 X 0.40 ❑ 0.60
Coated Surfaces	X 2 or 3 ❑ 2, 3, 4 or 5 ❑ 2 or 3 and 4 or 5
Glazing Spacing	❑ 1/4" Airspace X 1/2" Airspace
Gas Fill between Panes	X Air ❑ Argon ❑ Krypton

CEC ALTERNATIVE DEFAULT FENESTRATION U-FACTOR =	0.66	From Assembly U-Factors - Appendix B, Table B-14 (Insert value in above gray box next to U-factor)

DEFAULT SOLAR HEAT GAIN COEFFICIENT

SHGC for Center of Glass	SHGCc =	0.40	From Manufacturer's Documentation (Insert value "SHGCc" in equation below)
Calculate SHGC Fenestration Equation from Appendix B, Table B-12 (Site-Assembled)	$SHGC_{fen} = 0.08 + (0.86 \times SHGCc) =$	0.42	(Insert result value in above gray box next to SHGC)

ATTACHED MANUFACTURED DOCUMENTATION
Manufacturer's documentation must be attached showing the Product Type, Frame Type, Glazing Type, and SHGCc information needed to determine the Default U-factor and SHGC from the Applicable Table or equation.

PERSON TAKING RESPONSIBILITY FOR FENESTRATION COMPLIANCE CONTACT PERSON:

Contact Person:

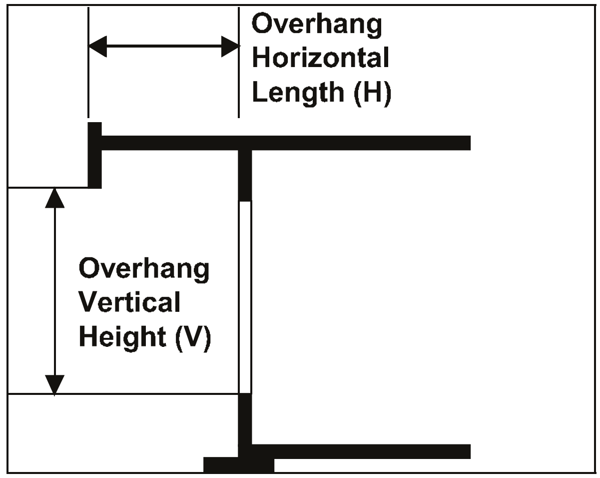
Company name and address:

Phone:	Fax:	Signature:

N. Relative Solar Heat Gain §143(a)5.C)

This value is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by an overhang factor. If an overhang does not exist, then the overhang factor is 1.0.

Figure 3-10– Overhang Dimensions



Overhang factor may either be calculated (see Equation 3-1) or may be taken from Table 3-13. The factor depends upon the ratio of the overhang horizontal length (H), and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-10. An overhang factor may be used *if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection (§143(a)5.C.ii).* The overhang projection is equal to the overhang length (H) as shown in Figure 3-10. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough to each side of the window.

Equation 3-1– Relative Solar Heat Gain

$$RSHG = SHGCwin \times OHF$$

Where

RSHG = Relative solar heat gain.

$SHGC_{win}$ = Solar heat gain coefficient of the window.

OHF = Overhang factor = $[1 + aH/V + b(H/V)^2]$

Where

H = Horizontal projection of the overhang from the surface of the window in feet, but no greater than V.

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

a = -0.41 for North-facing windows, -1.22 for South-facing windows, and -0.92 for East- and West-facing windows.

b = 0.20 for North-facing windows, 0.66 for South-facing windows, and 0.35 for East- and West-facing windows.

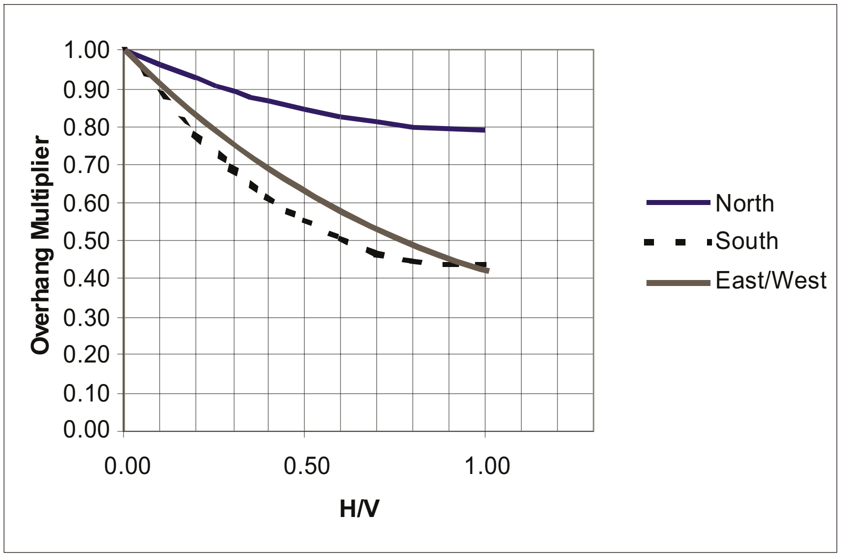
Table 3-13 - Overhang Factors

H/V	North	South	East/West
0.00	1.00	1.00	1.00
0.10	0.96	0.88	0.91
0.20	0.93	0.78	0.83
0.30	0.90	0.69	0.76
0.40	0.87	0.62	0.69
0.50	0.85	0.56	0.63
0.60	0.83	0.51	0.57
0.70	0.81	0.47	0.53
0.80	0.80	0.45	0.49
0.90	0.79	0.44	0.46
1.00	0.79	0.44	0.43

To use Table 3-13, measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cut-off point of the overhang (V). Then calculate H/V. Enter the table at that point. Move across to the column that corresponds to the orientation of the window and find the overhang factor. Note that any value of H/V greater than one has the same overhang factor (for a given orientation).

Figure 3-11 graphs the overhang factors of the various orientation as a function of H/V. It shows that overhangs have only a minor effect on the north (maximum reduction in SHGC is only about 20 percent). East, west and south overhangs can achieve reductions of 55 - 60 percent. The benefits of the overhang level off as the overhang becomes large. (Note: this graph is presented only to illustrate the benefits of overhangs. Do not use the graph to scale values of the overhang factor; use Table 3-13 or calculate the value directly from Equation 3-1.)

Figure 3-11– Graph of Overhang Factors



Example 3-3– RSHG Calculation

Question

An east-facing window has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends three feet out from the plane of the glass (H=3), and is six feet above the bottom of the glass (V=6). The overhang extends more than three feet beyond each side of the glass and the top of the window is less than two feet vertically below the overhang. What is the RSHG for this window?

Answer

First, calculate H/V. This value is 3 / 6 = 0.50. Next, find the overhang factor from Table 3-13. For east-facing windows, this value is 0.63. Finally, multiply it by the solar heat gain coefficient to obtain the RSHG: 0.63 x 0.71 = 0.45 = RSHG.

3.2 Envelope Design Procedures

3.2.1 Mandatory Measures

The mandatory measure requirements apply to new construction, additions and altered envelope components.

A. Doors, Windows and Skylights (§116)

The mandatory measures for doors, windows and skylights address the air-tightness of the units and how their U-factor and SHGC are determined. Fenestration products must be labeled with a U-factor and SHGC and the manufacturer or an independent certifying organization must certify that the product meets the air infiltration requirements of §116(a). Site-built fenestration in large projects (more than 100,000 ft² of floor area and more than 10,000 ft² of site-built vertical fenestration area) must have a label certificate issued by NFRC that is filed in the contractors project office during construction and in the building managers office after construction.

Doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-14. For field-fabricated products or an exterior door, the *Standards* require that the unit be caulked, gasketed, weather-stripped or otherwise sealed (§116(b)). Unframed glass doors and fire doors are the two exceptions to these requirements.

Where possible, it is best to decide what make and model of fenestration will be used before completing compliance documents. This enables the use of NFRC certified data to be used for compliance purposes. For site-built fenestration products, the label certificate will likely be generated by the glazing contractor after the construction project is awarded. For compliance purposes, the designer should select a U-factor and SHGC for the fenestration system that is reasonable and achievable. For U-factor, Appendix B should be used as a guide. The SHGC equations (see above) in combination with SHGC data for glazing materials should be used to determine a reasonable value for SHGC to use for compliance purposes.

Table 3-14 - Maximum Air Infiltration Rates

Class	Type	Rate
Windows (CFM/ft²) of window area	All	0.3
Residential Doors (CFM/ft²) of door area	Swinging, Sliding	0.3
All Other Doors (CFM/ft²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

B. Joints and Openings (§117)

The basic requirement of this section is that all joints and other openings in the building envelope that are potential sources of air leakage be caulked, gasketed, weather-stripped, or otherwise sealed to limit air leakage into or out of the building. This applies to penetrations for pipes and conduits, ducts, vents and other openings. It means that all gaps between wall panels, around doors Ceiling joints, lighting fixtures, plumbing openings, doors and windows, and other construction joints must be well sealed.

Ceiling joints, lighting fixtures, plumbing openings, doors and windows should all be considered as potential sources of unnecessary energy loss due to infiltration. No special construction requirements are necessary for suspended (T-bar) ceilings. Standard construction (insulation on ceiling tiles) is adequate for meeting the infiltration/exfiltration requirements.

C. Insulation Materials (§118)

The California Quality Standards for Insulating Materials, which became effective on January 1, 1982, ensure that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Manufacturers must certify insulating materials to comply with California Quality Standards for Insulating Materials. Builders may not install the types of insulating materials listed in Table 3-15 unless the product has been certified by the manufacturer. Builders and enforcement agencies should use the Department of Consumer Affairs *Consumer Guide and Directory of Certified Insulation Material* to check compliance. (Note this is not an *Energy Commission* publication.) If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Thermal Insulation Program at (916) 574-2046.

The California Quality Standards for Insulating Materials also require that all exposed installations of faced mineral fiber and mineral aggregate insulations must use fire retardant facings that have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

Flames spread rating and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

Table 3-15 - Certified Insulating Materials

Type	***Form***
Aluminum foil	Reflective foil
Cellular glass	Board form
Cellulose fiber	Loose fill and spray applied
Mineral aggregate	Board form
Mineral fiber	Blankets, board form, loose fill
Perlite	Loose fill
Phenolic	Board form
Polystyrene	Board form, molded extruded
Polyurethane	Board form and field applied
Polyisocyanurate	Board form and field applied
Urea formaldehyde	Foam field applied
Vermiculite	Loose fill

D. Demising Walls (§118(e))

Demising walls separating conditioned space from enclosed unconditioned space must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. This requirement applies to buildings meeting compliance under the prescriptive or performance approach. This requirement assures at least some insulation in a wall where an adjoining space may remain unconditioned indefinitely.

3.2.2 Prescriptive Envelope Component Approach (§143(a))

The Envelope Component Approach is the simplified approach. Under this approach, each of the envelope assemblies (walls, roofs, floors, windows, skylights) complies individually with its requirement. If one piece of the envelope does not comply, the entire envelope does not comply. The simplicity of this approach means there can be no trade-offs between components. If one or more of the envelope components cannot meet its requirement, the alternative is to use either the Overall Envelope or the Performance Approach, either of which allows trade-offs between components.

Under the Envelope Component Approach, the requirement for each opaque (non-glazing) component takes one of two forms: R-value of its insulation or overall U-factor of the assembly. Glazing component requirements address U-factor, solar heat gain coefficient, and an upper limit on glazing area. The requirements are found in Table 3-22 and Table 3-23 with applicable excerpts in the following sections. The requirements vary by climate zone, occupancy and, in some cases, heat capacity. Compliance is demonstrated on the ENV-2, Envelope Component Method form.

A. Exterior Roofs and Ceilings (§143(a)1)

Exterior roofs or ceilings can meet the component requirements in one of two ways (see Figure 3-12) - install the required R-value of insulation (see Table 3-17), or demonstrate that the overall U-factor of the assembly meets the required U-factor (§141(c)4). If the insulation by itself meets the R- value requirement, then that component complies with this approach. If not, then the U-factor calculation allows for the overall insulating qualities of the assembly, which also acknowledges the effects of wood or metal framing. For ceilings the effects of T-bar framing and metal lighting fixtures must be included in determining the overall U-factor of an assembly.

When recessed lights are not of Type IC (rated for insulation contact), the weighted average ceiling assembly is calculated as two parallel assemblies:

1. The effective R-value of the ceiling assembly is the sum of (a) T-bar/acoustic tile (to account for the metal grids, assume 1/2 the tile's R-value); (b) ceiling insulation; and (c) two inside air film resistances (0.61 R-value per air film).

2. The effective R-value of the light fixtures is calculated as the sum of two inside air film resistances (0.61 R-value per air film). If the fixtures include plastic diffusers, the R-value of the light fixture should be calculated as two air film resistances and a 1.5 inch air space (0.77 R-value).

Note: When fixtures are IC-rated and covered by insulation, the insulation R-value alone may be used to show compliance with the prescriptive requirements or the above calculation can be modified to include the insulation R-value in the light fixture assembly.

The two parallel assemblies are then weight averaged and the overall U-factor calculated.

Note: You cannot use the EZFRAME program for T-bar/drop ceiling assemblies.

When envelope calculations are prepared before the lighting plan, the following default values (Table 3-16) may be used to determine the percentage of the ceiling assembly made up of light fixtures:

Table 3-16 - Default Light Fixture Percentages for General Commercial and Industrial Buildings

Building Type	***Percent of Ceiling as Lighting Fixture***
Work Buildings	10%
Grocery	15%
Industrial/Commercial Storage	7%
Medical Buildings	12%
Office Building	12%
Religious Worship, Auditorium, and Convention Center	16%
Restaurants	12%
Retail and Wholesale	16%
Schools	15%
Theaters	12%
All Others	7%

Figure 3-12– Roof/Ceiling Flowchart

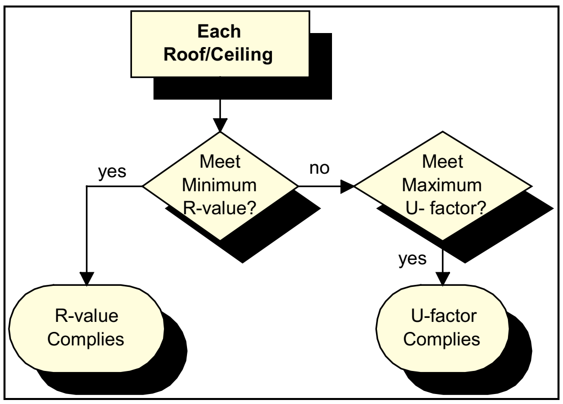


Table 3-17 - Roof/Ceiling Requirements

		Climate Zones				
Space Type	Criterion*	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	19	19	11	19	19
	U-factor	0.057	0.057	0.078	0.057	0.057
Residential High-rise	R-value	30	19	19	30	30
	U-factor	0.037	0.051	0.051	0.037	0.037

*U-factors are the actual conductance of the entire assembly. R-values refer to the nominal R-value of the insulation within the framing.

B. Exterior Walls (§143(a)2)

Exterior walls can meet the component requirements in one of two ways (see Figure 3-13) - install the required R-value of insulation (see Table 3-18), or demonstrate that the overall U-factor of the assembly meets the required U-factor (§141(c)4). If the insulation by itself meets the R-value requirement, then that component complies under this approach. If not, then the U-factor calculation allows credit for the overall insulating qualities of the assembly, which includes accounting for the effects of wood or metal framing in the assembly.

The required U-factor depends on the type of wall construction. There are five classes of wall: wood frame, metal frame, medium mass, high mass and other. The “other” category is used for any wall type that does not fit into one of the other four wall classes. The mass walls are distinguished by their heat capacity (HC); the higher the HC, the higher the wall U-factor may be (see Heat Capacity discussion in Section 3.1.2G). Medium mass walls have an HC between 7 Btu/ft^2-°F and 15 Btu/ft^2-°F. High mass walls have an HC greater than 15 Btu/ft^2-°F .

Framed wall assemblies will seldom have an HC greater than 7 Btu/ft^2-°F . Medium mass walls will have at least one fairly heavy layer, such as two coat stucco or a brick veneer, in order to have an HC higher than 7 Btu/ft^2-°F. High mass walls are generally of masonry or concrete construction.

The proposed wall U-factor must be calculated by an appropriate method (see §141(c)4). Framed assemblies must account for framing affects. Masonry assemblies must account for two dimensional heat flow. See Section 3.1.2D, E, and F for a complete discussion of the various methods and forms for determining U-factors.

Figure 3-13– Wall Flowchart

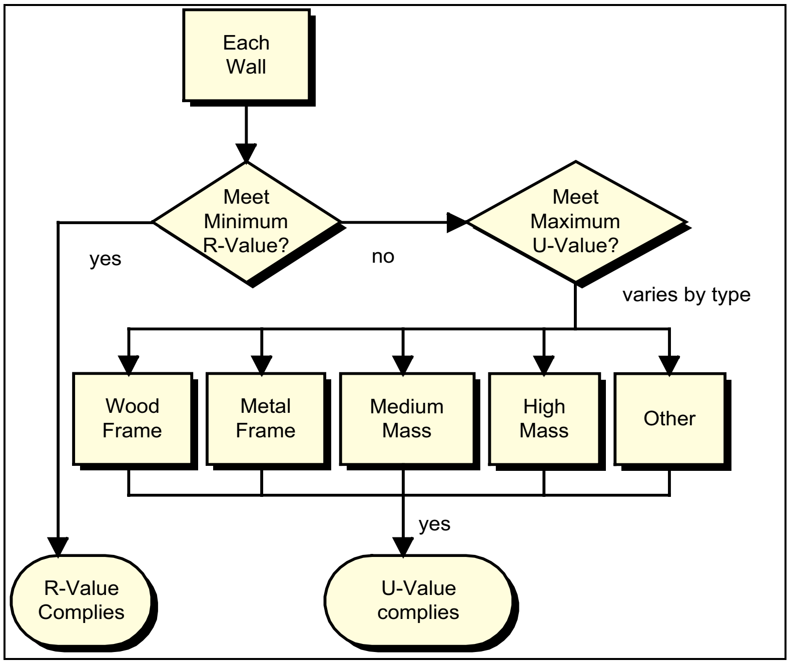


Table 3-18 - Wall Requirements

		Climate Zones				
Space Type	Criterion	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	13	11	11	13	13
	U-factor					
	Wood frame	0.084	0.092	0.092	0.084	0.084
	Metal frame	0.182	0.189	0.189	0.182	0.182
	Mass/7.0 HC 15.0	0.340	0.430	0.430	0.430	0.430
	Mass/15.0 HC	0.360	0.650	0.690	0.650	0.400
	Other	0.084	0.092	0.092	0.084	0.084
Residential High-rise	R-value	19	19	11	19	19
	U-factor					
	Wood frame	0.063	0.092	0.092	0.084	0.084
	Metal frame	0.140	0.181	0.181	0.175	0.175
	Mass/7.0 HC 15.0	0.340	0.430	0.430	0.430	0.430
	Mass/15.0 HC	0.360	0.650	0.690	0.650	0.400
	Other	0.063	0.092	0.092	0.084	0.084

C. Demising Walls (§143(a)3 & 5)

Demising walls, separating conditioned space from enclosed unconditioned space, must be insulated with a minimum of R-11 insulation if the wall is a framed assembly. If it is not a framed assembly, then no insulation is required. This only applies to the opaque portion of the wall. A *demising wall* is not an *exterior wall.*

The rationale for insulating demising walls is that the space on the other side may remain unconditioned indefinitely. For example, the first tenant in a warehouse building cannot know whether the future neighbor will use the adjoining space as unheated warehouse space or as an office. This requirement assures at least some insulation in the wall.

D. Exterior Floors and Soffits (§143(a)4)

Exterior floors and soffits can meet the component requirements using two methods (see Figure 3-14) - install the required R-value of insulation (see Table 3-19), or demonstrate that the overall U-factor of the assembly meets the required U-factor (see §141(c)4). The U-factor calculation allows for calculating the overall insulating qualities of the entire assembly, which includes accounting for the effects of wood or metal framing in the assembly.

Figure 3-14– Floor/Soffit Flowchart

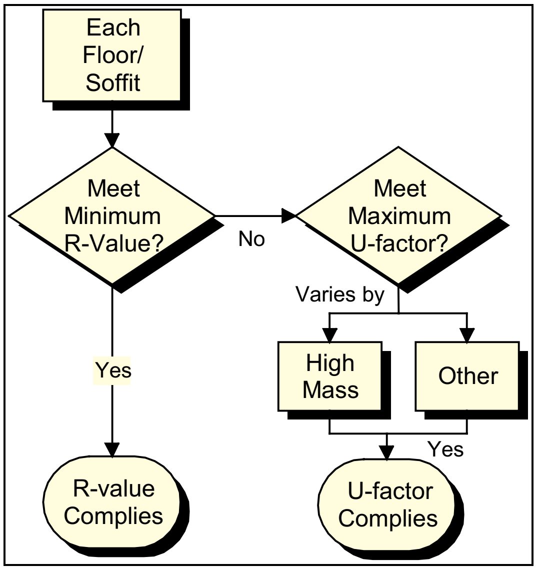


Table 3-19 - Floor/Soffit Requirements

		Climate Zones				
Space Type	Criterion	1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	R-value	19	11	11	11	11
	U-factor					
	Mass/7.0 HC	0.097	0.158	0.158	0.097	0.158
	Other	0.05	0.076	0.076	0.076	0.076
Residential High-rise	R-value	19	11	11	11	11
	U-factor					
	Mass/7.0 HC	0.097	0.158	0.158	0.097	0.158
	Other	0.05	0.076	0.076	0.076	0.076
	Raised concrete R-value	8	*	*	*	*

* Required insulation levels for concrete raised floors are R-8 in Climate Zones 2, 11, 13, and 14; R-4 in Climate Zones 12 and 15, and R-0 in Climate Zones 3 through 10.

The required U-factor depends on the type of floor construction: mass and other. The mass floor is distinguished by its heat capacity (HC), which must be greater than 7 (see Heat Capacity discussion in Section 3.1.2G).

Particular note should be taken with this requirement when insulating slab floors that are over unconditioned spaces, such as crawl spaces or parking garages.

Because there are no cavities to accept the insulation, it must be applied either to the underside of the slab or above the slab and beneath the finished floor. There are numerous ways this can be accomplished, but the selection requires careful consideration of the requirements for finishes above or below the insulation.

E. Windows (§143(a)5)

There are three aspects of the Envelope Component Approach for windows:

1. Maximum Area
2. Maximum U-factor
3. Maximum Relative Solar Heat Gain

Under the Envelope Component Approach, the total window area may not exceed 40 percent of the gross wall area for the building (see Section 3.1.2A for the definitions of how these are measured). This maximum area requirement will affect those buildings with very large glass areas, such as automobile showrooms or airport terminals.

Optionally, multiply the length of the display perimeter by six feet in height and use the larger of the product of that multiplication or 40 percent of gross wall area.

Each window or skylight must meet the required U-factor and Relative Solar Heat Gain (see Table 3-20). The required value for Relative Solar Heat Gain (RSHG) is less stringent (higher) for north-facing windows. The "north" value may also be used for windows in the first floor display perimeter which are prevented from having an overhang because of building code restrictions (such as minimum separation from another building or a property line) (exception to §143(a)5.C). Beginning with the 2001 update, the Relative Solar Heat Gain criteria also depends on the window-wall ratio, becoming more stringent with larger window areas.

Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the U-factor and RSHG requirement for the climate zone.

Note also that the RSHG limitation allows credit for window overhangs. In order to get credit for an overhang, it must extend beyond both sides of the window jamb by a distance equal to the overhang projection (§143(a)5.C.ii). This would occur naturally with a continuous eave overhang, but may require special attention in some designs. See Section 3.1.2J for more information on RSHG.

Table 3-20 - Window Requirements

		Climate Zones									
Space Type	Criterion	1,16		3-5		6-9		2,10-13		14, 15	
Nonresidential	U-factor	0.49		0.81		0.81		0.49		0.49	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR[1]	0.49	0.72	0.61	0.61	0.61	0.61	0.47	0.61	0.46	0.61
	11-20% WWR	0.43	0.49	0.55	0.61	0.61	0.61	0.36	0.51	0.36	0.51
	21-30% WWR	0.43	0.47	0.41	0.61	0.39	0.61	0.36	0.47	0.36	0.47
	31-40% WWR	0.43	0.47	0.41	0.61	0.34	0.61	0.31	0.47	0.31	0.40
Residential High-rise	U-factor	0.49		0.49		0.49		0.49		0.49	
	Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
	0-10% WWR	0.46	0.68	0.41	0.61	0.47	0.61	0.36	0.49	0.36	0.47
	11-20% WWR	0.46	0.68	0.40	0.61	0.40	0.61	0.36	0.49	0.31	0.43
	21-30% WWR	0.36	0.47	0.31	0.61	0.36	0.61	0.31	0.40	0.26	0.43
	31-40% WWR	0.30	0.47	0.26	0.55	0.31	0.61	0.26	0.40	0.26	0.31

1 WWR = Window Wall Ratio

F. Skylights (§143(a)6)

As with windows, there are three aspects of the Envelope Component Approach for skylights:

1. Maximum Area
2. Maximum U-factor
3. Maximum Solar Heat Gain Coefficient

The area limitation for skylights is based on 5 percent of the gross exterior roof area. This effectively prevents large skylights under the Envelope Component Approach. The limit increases to 10 percent for buildings with an atrium over 55 feet high (see Section 3.1.2A for definition). The 55-foot height is also the height limitation at which the Uniform Building Code requires a mechanical smoke-control system for such atriums UBC Sec. 1715). This means that the 10 percent skylight allowance is not allowed for atriums unless they also meet this smoke control requirement. All skylights must meet the maximum U-factor.

Note that skylights are only regulated for SHGC, not RSHG, because skylights cannot have overhangs. With the 2001 update, the SHGC criteria varies with the skylight to roof ratio (SRR). Two ranges are represented in the standard: up to and including 2% of the exterior roof and greater than 2%, but less than or equal to 5%.

Table 3-21 - Skylight Requirements

			Climate Zones				
			1,16	3-5	6-9	2,10-13	14, 15
Nonresidential	U-factor	Glass w/Curb	0.99	1.18	1.18	0.99	0.99
		Glass wo/Curb	0.57	0.68	0.68	0.57	0.57
		Plastic w/Curb	0.87	1.30	1.30	1.10	1.10
	SHGC Glass	0-2% SRR[1]	0.68	0.79	0.79	0.46	0.46
		2.1-5% SRR	0.46	0.40	0.40	0.36	0.36
	SHGC Plastic	0-2% SRR	0.77	0.79	0.77	0.77	0.71
		2.1-5% SRR	0.58	0.65	0.62	0.62	0.58
Residential High-rise	U-factor	Glass w/Curb	0.99	1.18	1.18	0.99	0.99
		Glass wo/Curb	0.57	0.68	0.68	0.57	0.57
		Plastic w/Curb	0.87	1.30	1.30	1.10	0.87
	SHGC Glass	0-2% SRR	0.46	0.58	0.61	0.46	0.46
		2.1-5% SRR	0.36	0.32	0.40	0.32	0.31
	SHGC Plastic	0-2% SRR	0.71	0.65	0.65	0.65	0.65
		2.1-5% SRR	0.55	0.39	0.65	0.34	0.27

1 SRR = Skylight Roof Ratio

For skylights, the U-factor and solar heat gain coefficient (SHGC) criteria is different depending on whether the skylight glazing material is plastic or glass. For glass skylights, the U-factor criteria depends on whether or not the skylight is intended to be mounted on a curb. It is assumed that all plastic skylights are intended to be mounted on a curb. As discussed above, the U-factor for skylights includes heat losses through the glazing, the frame and the curb (when one exists).

G. Exterior Doors §143(a)7)

Opaque doors have no R-value, U-factor or area requirements. Exterior doors are only a part of the compliance process when they are included in the calculation of the gross exterior wall area. Glazing in doors, however, is defined as a window in the *Standards* when glazing exceeds one-half of the area of the door and must be included in all window calculations.

3.2.3 Prescriptive Overall Envelope Approach (§143(b))

The Overall Envelope Approach is the second prescriptive envelope approach. It offers the greater design flexibility of the prescriptive envelope approaches. It allows the designer to make trade-offs between many of the building envelope components. For example, if a designer finds it difficult to insulate the walls to a level adequate for meeting the wall component U-factor requirement, then the insulation level in a roof or floor or the performance of a window component could be increased to offset the under-insulated wall. The same holds true for glazing. If a designer wants to put clear, west-facing glass to enhance the display of merchandise in a show window, it would be possible to use lower SHGC glazing on the other orientations to make up for the increased SHGC on the west.

The Overall Envelope Approach has two parts and both parts must be met: overall heat loss (see Equations 3-2 and 3-3) and overall heat gain (see Equations 3-4 and 3-5). The overall heat loss accounts for the insulating qualities of the building, and sets a maximum rate of conductive heat transfer through the building envelope. The requirements are more stringent in more extreme climate zones than in mild climate zones. The overall heat gains accounts for the area of windows and skylights and their ability to block solar heat gains, thereby reducing cooling loads on the building. Cool roofs are also accounted for in the overall heat gain calculations. The heat gain requirements are more stringent in warmer climate zones.

A *standard value* and a *proposed value* are calculated for both the overall heat loss and the overall heat gain using ENV-2: Overall Envelope Method found in Section 3.3.3. These calculations assume that the standard building complies with the requirements of the Envelope Component Approach (also calculated on ENV-2: Overall Envelope Method). The standard values are compared to the proposed values calculated from the actual envelope design. If the proposed values do not exceed the standard values, then the Overall Building Envelope requirements are met.

Table 3-22 - Nonresidential Requirements (except High-Rise Residential and Hotel/Motel Guest Room)

	Climate Zones 1,16		3-5		6-9		2,10-13		14, 15	
Roof/Ceiling										
R-value or	19		19		11		19		19	
U-factor	0.057		0.057		0.078		0.057		0.057	
Wall										
R-value or	13		11		11		13		13	
U-factor										
Wood frame	0.084		0.092		0.092		0.084		0.084	
Metal frame	0.182		0.189		0.189		0.182		0.182	
Mass/7.0 HC 15.0	0.340		0.430		0.430		0.430		0.430	
Mass/15.0 HC	0.360		0.650		0.690		0.650		0.400	
Other	0.084		0.092		0.092		0.084		0.084	
Floor/Soffit										
R-value or	19		11		11		11		11	
U-factor										
Mass/7.0 HC	0.097		0.158		0.158		0.097		0.158	
Other	0.050		0.076		0.076		0.076		0.076	
Window U-factor	0.49		0.81		0.81		0.49		0.49	
Window Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
0-10% WWR[1]	0.49	0.72	0.61	0.61	0.61	0.61	0.47	0.61	0.46	0.61
11-20% WWR	0.43	0.49	0.55	0.61	0.61	0.61	0.36	0.51	0.36	0.51
21-30% WWR	0.43	0.47	0.41	0.61	0.39	0.61	0.36	0.47	0.36	0.47
31-40% WWR	0.43	0.47	0.41	0.61	0.34	0.61	0.31	0.47	0.31	0.40
Skylight U-factor Glass w/Curb	0.99		1.18		1.18		0.99		0.99	
Glass wo/Curb	0.57		0.68		0.68		0.57		0.57	
Plastic w/Curb	0.87		1.30		1.30		1.10		1.10	
Skylight SGHC Glass 0-2% SRR[2]	0.68		0.79		0.79		0.46		0.46	
2.1-5% SRR	0.46		0.40		0.40		0.36		0.36	
Skylight SHGC Plastic 0-2% SRR	0.77		0.79		0.77		0.77		0.71	
2.1-5% SRR	0.58		0.65		0.62		0.62		0.58	

1 WWR = Window Wall Ratio
2 SRR= Skylight Roof Ratio

Table 3-23 - High-Rise Residential and Hotel/Motel Guest Room Requirements

	Climate Zones									
	1,16		3-5		6-9		2,10-13		14, 15	
Roof/Ceiling										
R-value or	30		19		19		30		30	
U-factor	0.037		0.051		0.051		0.037		0.037	
Wall										
R-value or	19		11		11		13		13	
U-factor										
Wood frame	0.063		0.092		0.092		0.084		0.084	
Metal frame	0.140		0.181		0.181		0.175		0.175	
Mass/7.0 HC 15.0	0.340		0.430		0.430		0.430		0.430	
Mass/15.0 HC	0.360		0.650		0.690		0.650		0.400	
Other	0.063		0.092		0.092		0.084		0.084	
Floor/Soffit										
R-value or	19		11		11		11		11	
U-factor										
Mass/7.0 HC	0.097		0.158		0.158		0.097		0.097	
Other	0.050		0.076		0.076		0.076		0.076	
Raised concrete R-value	8		*		*		*		*	
Window U-factor	0.49		0.49		0.49		0.49		0.49	
Window Relative Solar Heat Gain	Non-North	North	Non-North	North	Non-North	North	Non-North	North	Non-North	North
0-10% WWR[1]	0.46	0.68	0.41	0.61	0.47	0.61	0.36	0.49	0.36	0.47
11-20% WWR	0.46	0.68	0.40	0.61	0.40	0.61	0.36	0.49	0.31	0.43
21-30% WWR	0.36	0.47	0.31	0.61	0.36	0.61	0.31	0.40	0.26	0.43
31-40% WWR	0.30	0.47	0.26	0.55	0.31	0.61	0.26	0.40	0.26	0.31
Skylight U-factor Glass w/Curb	0.99		1.18		1.18		0.99		0.99	
Glass wo/Curb	0.57		0.68		0.68		0.57		0.57	
Plastic w/Curb	0.87		1.30		1.30		1.10		0.87	
Skylight SGHC Glass 0-2% SRR[2]	0.46		0.58		0.61		0.46		0.46	
2.1-5% SRR	0.36		0.32		0.40		0.32		0.31	
Skylight SHGC Plastic 0-2% SRR	0.71		0.65		0.65		0.65		0.65	
2.1-5% SRR	0.55		0.39		0.65		0.34		0.27	

* Required insulation levels for concrete raised floors are R-8 in Climate Zones 2, 11, 13, and 14; R-4 in Climate Zones 12 and 15, and R-0 in Climate Zones 3 through 10.

1 WWR = Window Wall Ratio

2 SRR= Skylight Roof Ratio

Associated with the increased design flexibility afforded by the Overall Envelope Approach is an increase in complexity of the calculations when demonstrating compliance. Special attention must be given to the calculations because the effects of all the envelope components are interrelated. Changing any one component may prevent the overall envelope from complying. Improvements to one or more of the other components will be needed to bring the envelope into compliance.

Equation 3-2– Standard Building Heat Loss

$$HL_{std} = \sum_{i=1}^{nW} A_{Wi} \, U_{Wi_{std}} + \sum_{i=1}^{nF} A_{Fi} \, U_{Fi_{std}} + \sum_{i=1}^{nR} A_{Ri} \, U_{Ri_{std}} + \sum_{i=1}^{nG} A_{Gi} \, U_{Gi_{std}} + \sum_{i=1}^{nS} A_{Si} \, U_{Si_{std}}$$

Where

HL_{std} = Overall heat loss of the standard building (in Btu/h-°F).

i = Each wall type and orientation, floor/soffit type, roof/ceiling type, window and glazed door (glazing and frame) type and orientation, or skylight type for the standard building.

nW, nR,

nG, nF

nS = Number of components of the applicable envelope feature.

A_{Wi} = Exterior wall area on the north, east, south, and west orientations of the proposed building (in ft.^{2}) including the window area on that orientation of the proposed building, minus A_{Gi}. The standard building has as many walls in each orientation as there are HC categories in that orientation of the proposed building.

A_{Fi} = Exterior floor/soffit area of the proposed building (in ft.^{2}). The standard building has as many floors/soffits as there are HC categories in the floors/soffits of the proposed building.

A_{Ri} = Exterior roof/ceiling area of the proposed building (in ft.^{2}) plus the skylight area of the proposed building, less A_{Si}.

A_{Gi} = Window (glazing) area of each type on the north, east, south, and west orientations of the standard building (in ft.^{2}). If the total window wall ratio of the proposed building is more than 40 percent, the total window area is the greater of (a) 40 percent of the gross exterior wall area, or (b) six feet times the display perimeter.

The window area of each type and on each orientation of the standard design shall be decreased in proportion to the area in the proposed design according to one of the following formulas as applicable:

(a)

$$A_{Gi\ \ adj} \quad \frac{A_{Gi\ \ prop}}{A_{Gtotal\ \ prop}} x0.40xA_{Wtotal\ \ prop}$$

(b)

$$A_{Gi\ \ adj} \quad \frac{A_{Gi\ \ prop}}{A_{Gtotal\ \ prop}} x(6\ x\ Display\ Perimeter)$$

If the total window area of the proposed building is less than 10 percent of the gross exterior wall area, the window area of each type and on each orientation of the standard design shall be increased in proportion to the area in the proposed design according to the following formula:

$$A_{Gi\ \ adj} \quad \frac{A_{Gi\ \ prop}}{A_{Gtotal\ \ prop}} x0.10xA_{Wtotal\ \ prop}$$

Where:

$A_{Gi\text{-}adj}$ = Adjusted window area of each type on the north, east, south, and west orientations (in ft.^{2}).

$A_{Gi\text{-}prop}$ = Actual proposed window area of each type in the respective orientation (in ft.^{2}).

$A_{Gtotal\text{-}prop}$ = Total actual proposed window area of the proposed building (in ft.^{2}).

$A_{Wtotal\text{-}prop}$ = Total actual proposed gross exterior wall area of the proposed building (in ft.^{2}).

A_{Si} = Skylight area of the standard building for each skylight type (in ft.^{2}). The total skylight area in the standard building is equal to the total skylight area of the proposed building or five percent of the gross exterior roof area (or, for atria over 55 feet high, 10 percent of the gross exterior roof area), whichever is less. If the total skylight area of the proposed building is more than five percent of the gross exterior roof area or more than 10 percent of the gross exterior roof area for atria over 55 feet high, the skylight area of each type of the standard building shall be decreased in proportion to the area in the proposed design according to the following formula:

$$A_{Si\ \ adj} \qquad \frac{A_{Si\ \ prop}}{A_{Stotal\ \ prop}} x0.10xA_{Rtotal\ \ prop}$$

for atria over 55 feet high, and

$$A_{Si\ \ adj} \qquad \frac{A_{Si\ \ prop}}{A_{Stotal\ \ prop}} x0.05xA_{Rtotal\ \ prop}$$

for others, where:

$A_{Si\text{-}adj}$ = Adjusted skylight area of each type (in $ft.^2$).

$A_{Si\text{-}prop}$ = Actual proposed skylight area of each type (in $ft.^2$).

$A_{Stotal\text{-}prop}$ = Total actual proposed skylight area of the proposed building (in $ft.^2$).

$A_{Rtotal\text{-}prop}$ = Total actual proposed gross exterior roof area of the proposed building (in $ft.^2$).

U_{Wistd} = The applicable wall U-value for the corresponding AWi from Table 1-H or 1-I.

U_{Fistd} = The applicable floor/soffit U-value for the corresponding AFi from Table 1-H or 1-I.

U_{Ristd} = The applicable roof/ceiling U-value for the corresponding ARi from Table 1-H or 1-I.

U_{Gistd} = The applicable window U-value for the corresponding AGi from Table 1-H or 1-I.

U_{Sistd} = The applicable skylight U-value for the corresponding ASi from Table 1-H or 1-I.

A. Overall Heat Loss

There are two parts to the Overall Heat Loss calculation. The first is to calculate the Standard Building Heat Loss; this becomes the standard that must be met. The second is to calculate the Proposed Building Heat Loss, which is compared to the standard to show that it does not exceed the Standard Building Heat Loss.

There are three steps to calculating the Standard Building Heat Loss:

Step 1 - Calculate areas of each type of envelope assembly (walls, windows, roofs, etc.). If glazing is too large or small, areas may require adjustment as directed on the ENV-2.

Step 2 - Determine allowed U-factors from Table 3-22 and Table 3-23.

Step 3 - Multiply and add to get Standard Building Heat Loss.

Each step will be discussed in turn.

Calculate Areas

First, identify each type of assembly in the building envelope. In a complex building, there could be many. Assemblies are different if they have different materials or thermal properties. For example, a steel stud framed wall with a 1" stucco exterior would be different from a steel stud framed wall with 4" brick cladding.

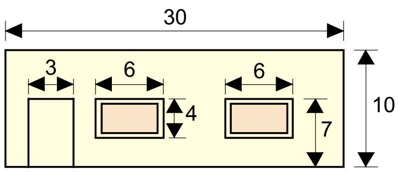
Next, calculate the areas of each assembly. All dimensions are taken at the exterior surface of the assembly. The sum of all the vertical surface areas is the gross exterior wall area (walls, windows, doors). The exterior wall area is the opaque wall area only (no doors). The window wall ratio is the total window area in the gross exterior walls, divided by the gross exterior wall area.

In the case of windows, the area is based on the rough opening dimensions. For most buildings, the actual window area is used to calculate the Standard Building Heat Loss.

Example 3-4– Area Calculation

Question

How is exterior wall area calculated for the following wall (dimensions in feet)?



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The door area is 3 x 7 = 21 ft^2. The window areas are 6 x 4 = 24 ft^2 each, or 48 ft^2 total. The exterior wall area is the gross minus doors and windows, or 300 ft^2 — 21 ft^2 — 48 ft^2 = 231 ft^2.

Adjust Areas

When the window wall ratio is less than 10 percent or more than 40 percent, an adjusted window area is used to calculate the Standard Building Heat Loss.

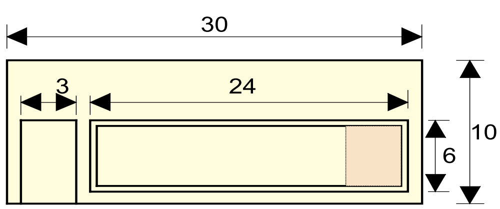
The first adjustment is for buildings with very little window area. The *Standards* allow for a minimum of 10 percent window wall ratio in calculating the standard envelope heat loss ("A_{Gi}" of Equation 3-2). If the actual window wall ratio is less than 10 percent, then an area equal to 10 percent of the gross exterior wall area is used for the standard building.

The second adjustment is for buildings with very large window area. If the actual window wall ratio is greater than 40 percent, then an area equal to 40 percent of the gross wall area is used to calculate the Standard Building Heat Loss. Alternatively, for buildings with substantial display perimeter areas (see 3.1.2A), an area equal to six feet high by the length of the display perimeter is calculated. If this value is greater than 40 percent of the gross exterior wall area, then it is used in the standard envelope heat loss calculation ("A_{Gi}" of Equation 3-2).

Example 3-5– Glazing Area Adjustments

Question

What is the window wall ratio (WWR) for the following wall (dimensions in feet)? How is the window and wall area adjusted under the overall envelope approach?



Answer

The gross exterior wall area is 30 x 10 = 300 ft^2. The window area is 24 x 6 = 144 ft^2. The WWR is 144 / 300 = 0.48, or 48 percent. The exterior wall area is 300 — 144 = 156 ft^2. The window area must be adjusted downward to 40 percent of the gross exterior wall area, or 0.40 x 300 = 120 ft^2. This is a window area reduction of 144 —120 = 24 ft^2. The exterior wall area must be increased by the same amount to 156 + 24 = 180 ft^2 (as shown by shaded area in sketch above).

If either of these adjustments is made to the standard window area, the exterior wall area is also adjusted (see Example 3-4). Skylights are treated similarly ("A_{Si}" of Equation 3-2). The actual skylight area or the rough opening area will be used to calculate the standard envelope heat loss. If the skylight is site-built (as in the case of large atrium roofs, malls, or other applications) and its shape is three-dimensional (not flat), then the area is the actual surface area, not the opening area (see definition of **Skylight Area** under Section 3.1.2A). If the skylight area is larger than 5 percent of the gross exterior roof area (roof doors not included for the standard building), then an area equal to 5 percent of the roof area is used. Alternatively, if the building has an atrium over 55 feet high, then the allowance for skylights are increased to 10 percent (or the actual skylight area if less than 10 percent of the gross roof area).

Determine Allowed U-factors

The allowed U-factors are taken from Table 3-22 and Table 3-23, depending on the occupancy type. These are the same values discussed under the Envelope Component Approach in the previous Section 3.2.2. It is necessary to differentiate wall assembly types and floor/soffit assembly types. The U-factor requirements depend on framing type and heat capacity of the wall or the floor/soffit. In the case of heavier construction assemblies, the heat capacity (see Section 3.1.2G) must be calculated before the allowed U-factor can be determined.

Multiply and Add

Once the areas and allowed U-factors are determined for each assembly, then the Standard Building Heat Loss can be calculated. For each assembly, the U-factor (U) and area (A) are multiplied together; the result is known as the *UA product* for the assembly. If any of the areas were adjusted, then the adjusted areas are used in this calculation. These UA products are added to obtain the total UA product for the building, which is the Standard Building Heat Loss.

The Standard Building Heat Loss has units of Btu/hr-°F, and it describes the amount of heat lost per hour through the building envelope for every degree Fahrenheit of temperature difference between inside and outside, under steady state heat flow conditions.

Equation 3-3– Proposed Building Heat Loss

$$HL_{prop} = \sum_{j=1}^{nW} A_{Wj} \times U_{Wj_{prop}} + \sum_{j=1}^{nF} A_{Fj} \times U_{Fj_{prop}} + \sum_{j=1}^{nR} A_{Rj} \times U_{Rj_{prop}} + \sum_{j=1}^{nG} A_{Gj} \times U_{Gj_{prop}} + \sum_{j=1}^{nS} A_{Sj} \times U_{Sj_{prop}}$$

Where

HL_{prop} = Overall heat loss of the proposed building (in Btu/h-°F).

j = Each wall type and orientation, floor/soffit type, roof/ceiling type, window and glazed door (glazing and frame) type and orientation, or skylight type for the proposed building.

nW, nR,

nG, nF,

nS = As determined in Equation 3-2.

A_{Wj} = Exterior wall area on the north, east, south, and west orientations of the proposed building (in ft.2). Each orientation has as many walls as there are HC categories.

A_{Fj} = Exterior floor/soffit area of the proposed building (in ft.2). There are as many floors/soffits as there are HC categories.

A_{Rj} = Exterior roof/ceiling area of the proposed building (in ft.2).

A_{Gj} = Window (glazing) area for each window type and orientation of the proposed building (in ft.2).

A_{Sj} = Skylight area for each skylight type of the proposed building (in ft.2).

U_{Wjprop} = The wall U-value for the corresponding A_{Wj}.

U_{Fjprop} = The floor/soffit U-value for the corresponding A_{Fj}.

U_{Rjprop} = The roof/ceiling U-value for the corresponding A_{Rj}.

U_{Gjprop} = The window U-value for the corresponding A_{Gj}.

U_{Sjprop} = The skylight U-value for the corresponding A_{Sj}.

Once the Standard Building Heat Loss rate is determined, the proposed design's heat loss rate can be calculated and the two can be compared. If the proposed heat loss rate does not exceed the standard, then the envelope complies with the heat loss criteria.

The proposed heat loss is calculated the same as the standard, except that the actual areas and U-factors of each assembly are used without adjustment. The actual U-factors are calculated as described in section 3.1.2C-F. It is not necessary to calculate the U-factor of opaque doors, as they are ignored in the overall heat loss calculations. Any glazing in doors, however, is considered a window and must be included in all window calculations.

The UA product is calculated for each surface, and these are totaled to arrive at the Proposed Building Heat Loss. It has the same units and meaning as the Standard Building Heat Loss (see above).

For a complete example of how the Standard Building Heat Loss and Proposed Building Heat Loss are calculated and compared using the ENV-2 form (see Section 3.3.2).

B. Overall Heat Gain

As with the overall heat loss, there are two parts to the Overall Heat Gain calculation. The first part is to calculate the Standard Building Heat Gain; this becomes the standard that must not be exceeded.

The second part is to calculate the Proposed Building Heat Gain; compare this to the standard and show that the proposed heat gain does not exceed the standard heat gain.

Equation 3-4– Standard Building Heat Gain

$$HG_{std} \sum_{i=1}^{nW} A_{Wi}\ U_{Wi_{std}}\ TF_i \sum_{i=1}^{nF} A_{Fi}\ U_{Fi_{std}}\ TF_i \sum_{i=1}^{nR} A_{Ri}\ U_{Ri_{std}}\ TF_i$$
$$+ \sum_{i=1}^{nG} A_{Gi}\ U_{Gi_{std}}\ TF_i \sum_{i=1}^{nS} A_{Si}\ U_{Si_{std}}\ TF_i \sum_{i=1}^{nG} WF_{Gi}\ A_{Gi}\ RSHG_{Gi_{std}}\ SF$$
$$+ \sum_{i=1}^{nS} WF_{Si}\ A_{Si}\ SHGC_{Si_{std}}\ SF \sum_{i=1}^{nR} WF_{Ri}\ A_{Ri}\ U_{Ri_{std}}\ \mathrm{Ristd}\ SF$$

Where

HG_{std} = Overall heat gain of the standard building (Btu/h).

i = As determined in Equation 3-2.

nW, nR,

nG, nF,

nS = As determined in Equation 3-2.

A_{Wi} = As determined in Equation 3-2.

A_{Fi} = As determined in Equation 3-2.

A_{Ri} = As determined in Equation 3-2.

A_{Gi} = As determined in Equation 3-2.

A_{Si} = As determined in Equation 3-2.

U_{Wistd} = As determined in Equation 3-2.

U_{Fistd} = As determined in Equation 3-2.

U_{Ristd} = As determined in Equation 3-2.

U_{Gistd} = As determined in Equation 3-2.

U_{Sistd} = As determined in Equation 3-2.

$RSHG_{Gistd}$ = The applicable relative solar heat gain for the corresponding A_{Gi}, from Table 3-21, Table 3-22 or Table 3-23 (unitless).

W_n, W_e,

W_s, WF_{Gi} = The applicable weighting factor for glazing for each orientation of the standard building, from Table 3-25 (unitless).

WF_{Si} = The applicable weighting factor for skylight of the standard building, from Table 3-25 (unitless).

WF_{Ri} = The applicable weighting factor for roof of the standard building, from Table 3-25 (unitless).

a_{Ristd} = A standard roof absorptivity of 0.70 for the corresponding A_{Ri}.

$SHGC_{Sistd}$ = The applicable solar heat gain coefficient for the corresponding A_{Si}, from Table 3-22 or Table 3-23 (unitless).

SF = The solar factor from Table 3-24.

TF_i = The temperature factor from Table 3-24.

There are four steps to calculating the Standard Building Heat Gain:

Step 1 - Calculate the area and determine the U-factor and temperature factor (Table 3-24) of each type of envelope assembly (walls, windows, roofs, etc.) [Same values as heat loss equations.] Window areas may require adjustment if too large or small.

Step 2 - Determine RSHG for north and non-north orientations, and SHGC for skylights (as per climate zone, occupancy and type); values are taken from Table 3-22 and Table 3-23.

Step 3 - Determine the weighting factors and solar factors for each orientation (as per climate zone) from Table 3-24.

Step 4 - Determine the applicable roof absorptivity value. This value is set at 0.7 for standard roofs (all roofs other than cool roofs).

Step 5 - Multiply and add to get Standard Building Heat Gain.

Each step will be discussed in turn.

Calculate Areas

The total area of envelope features and glazing and corresponding U-factors were determined earlier for the Standard Building Heat Loss calculation. A temperature factor (Table 3-24) is applied. Window area was adjusted when it was too large or too small for the standard area. This same total is used for the Standard Building Heat Gain Calculation, except that it is further broken down by orientation. Each window is assigned to the nearest cardinal orientation: east, west, north and south (see Section 3.1.2). A solar factor (Table 3-24) is applied to window and skylight areas.

As in the heat loss calculation, the window areas are calculated by the rough opening dimensions.

Adjust Areas

If the total window area was adjusted in the standard heat loss calculation, a similar adjustment is made here, except that it is applied to each orientation. For example, if the proposed window wall ratio is 50 percent, then the window must be reduced to 40 percent for the standard reduction. This translates to the glazing area on each orientation being reduced by 20 percent for the standard heat gain calculation.

Determine RSHG and SHGC

The values for RSHG and SHGC are found in Table 3-22 and Table 3-23. For windows, the standard relative solar heat gain (RSHG) differs depending on whether or not the window is north-facing (see Sections 3.1.2A, I and J for definitions). For skylights, the standard solar heat gain coefficient (SHGC) differs depending on whether the skylight glazing material is glass or plastic It also differs based on the ratio of its area to the gross exterior roof area- there are two categories for this ratio (0-2% and 2.1-5%).

The values of RSHG and SHGC also differ by climate zone. For the milder climate zones, 1, 3-9, and 16, higher values are allowed.

For the Standard Building Heat Gain calculation, the values of RSHG and SHGC are simply taken from the tables and entered into the calculations.

Example 3-6– RSHG Determination

Question

What is the RSHG value for an east-facing window in an office building in climate zone 8 if the WWR is 8%?

Answer

0.61 (Table 3-22)

Determine Temperature Factor

The temperature factor considers the effects of solar radiation striking envelope surfaces. The appropriate values are taken from Table 3-24 and entered into the calculations.

Table 3-24 - Temperature and Solar Factors

Climate Zone	Temperature Factor (TF) Envelope Construction			Solar Factor (SF) (Btu/hr. x ft.^{2})
	Light Mass	Medium Mass	Heavy Mass	
1	14	3	1	128
2	40	30	28	126
3	28	18	16	126
4	32	22	20	125
5	27	17	15	124
6	28	18	16	123
7	27	17	15	123
8	33	23	21	123
9	42	31	29	123
10	45	35	33	123
11	49	38	36	127
12	45	34	32	126
13	45	35	33	125
14	52	42	40	125
15	55	45	43	123
16	34	23	21	128

Light Mass: Heat Capacity < 7 Btu/ft²-°°F
Medium Mass: Heat Capacity >= 7 and
Heavy Mass: Heat Capacity >= 15

Determine Weighting Factors

Weighting factors in the heat gain equations account for the variation in solar radiation striking windows and skylights by orientation and climate zone. The appropriate values are taken from Table 3-25 and entered into the Envelope Form ENV-2 Part 5 of 6. For windows assume Light Mass value.

Table 3-25- Glazing Orientation and Roof Weighting Factors

Space Type	Climate Zone	WF_{north}	WF_{south}	WF_{west}	WF_{east}	WF_{sky}	WF_{roof}
Nonresidential	1	0.56	1.25	1.16	1.03	1.48	0.93
	2	0.56	1.30	1.18	0.96	2.34	1.12
	3	0.51	1.28	1.24	0.97	2.42	0.84
	4	0.55	1.20	1.24	1.01	2.53	0.96
	5	0.58	1.25	1.18	0.98	2.48	0.80
	6	0.56	1.23	1.21	1.00	2.40	0.84
	7	0.57	1.30	1.17	0.97	2.36	0.87
	8	0.60	1.26	1.14	1.00	2.47	0.98
	9	0.56	1.36	1.11	0.97	2.29	0.97
	10	0.60	1.38	1.07	0.95	2.19	1.02
	11	0.55	1.19	1.17	1.10	2.37	0.89
	12	0.55	1.17	1.21	1.07	2.40	0.92
	13	0.58	1.15	1.17	1.10	2.39	1.04
	14	0.57	1.17	1.20	1.07	2.46	1.13
	15	0.61	1.27	1.05	1.07	2.29	0.92
	16	0.51	1.27	1.15	1.07	2.20	1.03
Residential High-rise	1	0.50	1.24	1.23	1.03	1.36	0.82
	2	0.55	1.29	1.23	0.94	2.30	1.08
	3	0.47	1.28	1.29	0.96	2.42	0.80
	4	0.54	1.17	1.33	0.96	2.53	0.96
	5	0.49	1.28	1.25	0.97	2.48	0.77
	6	0.55	1.20	1.26	0.99	2.37	0.79
	7	0.55	1.28	1.21	0.96	2.37	0.88
	8	0.57	1.26	1.20	0.97	2.44	0.96
	9	0.53	1.39	1.14	0.94	2.24	0.93
	10	0.59	1.34	1.12	0.94	1.92	1.00
	11	0.53	1.14	1.27	1.06	2.23	0.88
	12	0.55	1.14	1.29	1.03	2.31	0.91
	13	0.57	1.12	1.27	1.05	2.27	1.02
	14	0.57	1.13	1.28	1.02	2.38	1.08
	15	0.59	1.26	1.12	1.03	2.26	0.90
	16	0.49	1.24	1.25	1.01	2.02	0.95

Example 3-7– Determining Weighting Factors

Question

What is the weighting factor for a south-facing window in climate zone 12 for an office building?

Answer

1.17 (Table 3-25)

Determine Solar Factor

The solar factor is used to account for solar radiation striking glazed surfaces. The appropriate values are taken from Table 3-24 and entered into the standard and proposed heat gain calculations.

Determine Roof Absorptivity Value

The roof absorptivity value accounts for solar radiation absorbed through the roof surface. A value of 0.7 is used for the standard building. For the proposed building, a value of 0.45 is used for eligible cool roofs and a value of 0.7 is used for standard roofs (all roofs other than cool roofs).

Eligible tile cool roofs are roofs tested to have a solar reflectance of 0.4 or greater and a thermal emittance of 0.75 or greater. Eligible single ply or liquid applied cool roofs are roofs tested to have a solar reflectance of 0.70 or greater and a thermal emittance of 0.75 or greater. Eligible liquid applied cool roofs will also have a thickness greater than 20 mils and meet minimum performance requirements.

Eligible cool roof packaging will contain a label listing these testing results.

Multiply and Add

Once the areas and the allowed RSHG, SHGC and weighting factor are determined for each glazing orientation, then the Standard Building Heat Gain can be calculated. For each window orientation, the adjusted area is multiplied by the RSHG value and the weighting factor. For each type of skylight, the adjusted areas are multiplied by the SHGC value and the weighting factor. If the window or skylight area was adjusted, the adjusted areas are used in this calculation. All of these products are added to obtain the Standard Building Heat Gain.

Once the Standard Building Heat Gain rate is determined, the proposed design heat gain rate can be calculated and the two can be compared. If the proposed heat gain rate does not exceed the standard, then the envelope complies with the heat gain criteria.

The proposed heat gain is calculated the same as the standard, except that the actual areas for each orientation, and the actual RSHG and SHGC are used. The determination of actual SHGC and RSHG are described above in Sections 3.1.2I and 3.1.2J.

For the windows on each orientation, the actual area, SHGC, overhang factor and weighting factor are multiplied together. For skylights, the actual area, SHGC and weighting factor are multiplied. For roofs, the actual area, U-factor, weighting factor and absorptivity value are multiplied. These are summed to obtain the Proposed Building Heat Gain.

Equation 3-5– Proposed Building Heat Gain

$$
\begin{aligned}
HG_{prop} = & \sum_{j=1}^{nW} A_{Wj} \times U_{Wj_{prop}} \times TF_j + \sum_{j=1}^{nF} A_{Fj} \times U_{Fj_{prop}} \times TF_j + \sum_{j=1}^{nR} A_{Rj} \times U_{Rj_{prop}} \times TF_j \\
& + \sum_{j=1}^{nG} A_{Gj} \times U_{Gj_{prop}} \times TF_j + \sum_{j=1}^{nS} A_{Sj} \times U_{Sj_{prop}} \times TF_j + \sum_{j=1}^{nG} WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j \times SF \\
& + \sum_{j=1}^{nS} WF_{Sj} \times A_{Sj} \times SHGC_{Sj_{prop}} \times SF + \sum_{j=1}^{nR} WF_{Rj} \times A_{Rj} \times U_{Rj_{prop}} \times \alpha_{Rj_{prop}} \times SF
\end{aligned}
$$

Where

HG_{prop} = Overall heat gain of the proposed building (Btu/h).

j = As determined in Equation 3-3.

nW, nR,

nG, nF,

nS = As determined in Equation 3-3.

A_{Wj} = As determined in Equation 3-3.

A_{Fj} = As determined in Equation 3-3.

A_{Rj} = As determined in Equation 3-3.

A_{Gj} = As determined in Equation 3-3.

A_{Sj} = As determined in Equation 3-3.

U_{Wjprop} = As determined in Equation 3-3.

U_{Fjprop} = As determined in Equation 3-3.

U_{Rjprop} = As determined in Equation 3-3.

U_{Gjprop} = As determined in Equation 3-3.

U_{Sjprop} = As determined in Equation 3-3.

$SHGC_{Gj}$ = The solar heat gain coefficient for the corresponding A_{Gj} (unitless)

$SHGC_{Sj}$ = The solar heat gain coefficient for the corresponding A_{Sj} (unitless).

OHF_{Gj} = The overhang factor for the corresponding A_{Gj} (unitless).

$OHF_{Gj} = 1 + aH/V + b(H/V)^2$

Where:

H = Horizontal projection of an overhang from the surface of the window, no greater than *V*, in feet.

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

a = -0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east- and west-facing windows.

b = 0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east and west-facing windows.

WF_{Gj} = The applicable weighting factor for each orientation of the building, from Table 3-25 (unitless).

WF_{Skyj} = The applicable weighting factor for skylight of the proposed building, from Table 3-25 (unitless).

WF_{Rj} = The applicable weighting factor for roof of the proposed building, from Table 3-25 (unitless).

a_{Rjstd} = The applicable roof absorptivity for the corresponding A_{Rj}. An absorptivity of 0.45 for cool roofs (as defined in §118). An absorptivity of 0.7 for all other roofs.

SF = The solar factor from Table 3-24.

TF_j = The temperature factor from Table 3-24.

For an example of how the Standard and Proposed Building Heat Gain are calculated and compared using the ENV-2 form (see Section Example 3-9).

Example 3-8– Determining Roof Absorptivity Value

Question

What roof absorptivity value should be used in the proposed design for a single ply roofing product labeled with a tested reflectance of 0.8 and tested emittance of 0.4?

Answer

0.7 (Tested emittance does not meet the requirement for an eligible cool roof)

Example 3-9 – Overall Envelope Approach

Question

A proposed building in San Diego is designed with single clear glass, which does not meet the prescriptive criteria for fenestration U-factor or SHGC. The building owner would prefer to upgrade insulation levels in the roofs and walls, rather than install double glass. Is it possible to comply with the *Standards* using this overall envelope method?

The building is two stories with 50,000 ft² of roof area and 180,000 ft² of gross wall area. The building has slab-on-grade floor construction. Exterior walls are constructed of 2x6 metal studs spaced at 16 in. on center. R-19 batt insulation is installed in the cavity and R-7 continuous insulation is installed on the exterior of the wall. The roof construction consists of 2x12 joists with R-38 insulation in the cavity. The roof qualifies as a cool roof with an initial reflectance greater than 0.70 and an emissivity greater than 0.75.

Fenestration area totals 18,000 ft² with 5,000 ft² on the north and south and 4,000 ft² on the east and west. The SHGC of the fenestration assembly is 0.78 and the U-factor is 1.22. All of the 5 ft high windows are shaded by overhangs with a 4 ft projection, located at the top of the window.

Answer

The Overall Envelop Approach can be used to demonstrate compliance. It is necessary to show that the proposed building has both a lower heat loss and a lower heat gain than a standard building that meets the minimum requirements of the prescriptive standards. Heat loss and heat gain are calculated using the equations from §143(b).

Heat loss for the standard building is 49,098 Btu/h-ºF as shown in the calculations below. The U-factors are taken from Table 3-22. The wall U-factor is based on a metal framed wall.

$$HL_{std} = \sum_{i=1}^{nW} A_{Wi} \times U_{Wi_{std}} + \sum_{i=1}^{nR} A_{Ri} \times U_{Ri_{std}} + \sum_{i=1}^{nG} A_{Gi} \times U_{Gi_{std}}$$

HL_{std} = 162,000x0.189 + 50,000x0.078 + 18,000x0.81

HL_{std} = 49,098 Btu/h-ºF

Heat loss for the proposed building is 35,610 Btu/h-ºF as shown in the calculations below. The wall and roof U-factors (0.075 and 0.039 respectively) are taken from Appendix B. The window U-factor of 1.22 is taken from NFRC ratings.

$$HL_{prop} = \sum_{j=1}^{nW} A_{Wj} \times U_{Wj_{prop}} + \sum_{j=1}^{nR} A_{Rj} \times U_{Rj_{prop}} + \sum_{j=1}^{nG} A_{Gj} \times U_{Gj_{prop}}$$

HL_{prop} = 162,000x0.075 + 50,000x0.030 + 18,000x1.22

HL_{prop} = 35,610 Btu/h-ºF

The proposed building has a lower heat loss than the standard building so the building meets the heat loss portion of the requirements. Next, the heat gain must be compared for both the proposed and standard building.

The heat gain for the standard building is 2,961,571 Btu/h as shown in the calculations below. The SHGC criteria for fenestration is 0.61 for all orientations (see Table 3-22).

$$\begin{aligned} HG_{std} = & \sum_{i=1}^{nW} A_{Wi} \times U_{Wi_{std}} \times TF_i + \sum_{i=1}^{nR} A_{Ri} \times U_{Ri_{std}} \times TF_i \\ & + \sum_{i=1}^{nG} A_{Gi} \times U_{Gi_{std}} \times TF_i + \sum_{i=1}^{nG} WF_{Gi} \times A_{Gi} \times RSHG_{Gi_{std}} \times SF \\ & + \sum_{i=1}^{nR} WF_{Ri} \times A_{Ri} \times U_{Ri_{std}} \times {}_{Ri_{std}} \times SF \end{aligned}$$

HG_{Std} = (162,000x0.189x27)

+(50,000x0.078x27)

+(18,000x0.81x27)

+[(0.57x5,000x0.61)+(0.97x4,000x0.61)+(1.30x5,000x0.61)+(1.17x4,000x0.61)]x123

+(0.87x50,000x0.078x0.70)x123

HG_{Std} = 2,961,571 Btu/h

The heat gain for the proposed building is 1,935,480Btu/h as shown in the calculations below. Note that the roof absorptance is entered as 0.45, the value prescribed for qualifying cool roofs.

$$
\begin{aligned}
HG_{prop} = {} & \sum_{j=1}^{nW} A_{Wj} \times U_{Wj_{prop}} \times TF_j + \sum_{j=1}^{nR} A_{Rj} \times U_{Rj_{prop}} \times TF_j \\
& + \sum_{j=1}^{nG} A_{Gj} \times U_{Gj_{prop}} \times TF_j + \sum_{j=1}^{nG} WF_{Gj} \times A_{Gj} \times SHGC_{Gj_{prop}} \times OHF_j \times SF \\
& + \sum_{j=1}^{nR} WF_{Rj} \times A_{Rj} \times U_{Rj_{prop}} \times \alpha_{Rj_{prop}} \times SF
\end{aligned}
$$

HG_{Prop} = (162,000x0.075x27)

+(50,000x0.030x27)

+(18,000x1.22x27)

+[(0.57x5,000x0.78x0.80)+(0.97x4,000x0.78x0.49)+(1.30x5,000x0.78x0.45)+(1.17x4,000 x0.78x0.49)]x123

+(0.87x50,000x0.030x0.45)x123

HG_{Prop} = 1,935,480 Btu/h

Since both the heat gain and heat loss of the proposed building is less than the standard building, the proposed building complies using the overall envelope approach.

3.2.4 Performance Approach

Under the performance approach, the energy use of the building is modeled using an energy budget generated by a computer program approved by the Energy Commission call the Energy Hotline for the latest version. This section presents some basic details on the modeling of building envelope components. *Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program.* All computer programs, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Section 6.1.

A. Modeling Envelope Components

The following modeling capabilities are required by all approved nonresidential computer programs. These modeling features affect the thermal loads seen by the HVAC system model.

Opaque Surface Mass Characteristics

Heat absorption, retention and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled. Typical inputs are thickness, density, specific heat and conductivity. See Section 3.1.2G for determining the heat capacity of materials.

Opaque Surface Heat Transfer

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

- Surface areas by opaque surface type. Section 3.1.2A discusses determining the area of opaque surfaces.
- Surface orientation and slope. Section 3.1.2A discusses how slope affects wall and roof/ceiling definitions.
- Thermal conductance of the surface. Section 3.1.2C through G discusses determining the U-factor of various assemblies.
- Surface absorptance. Surface absorptance is a restricted input (except for cool roofs). Section 6.1.3A discusses fixed and restricted modeling assumptions. Surface absorptance is a variable input in proposed design for roofs to provide a 'cool roof credit'. The roof reference design is set with a non-cool roof surface absorptance. The difference in surface absorptance creates a credit that can be used with both the building envelope trade-off option and the whole building performance method. Cool roofs have both a high reflectance and a high emittance. The high reflectance keeps much of the sun's energy from being absorbed and becoming a component of heat transfer. The high emittance ensures that when the roof does warm up, its heat can escape through radiation to the sky.

Glazing Heat Transfer

Heat transfer through all glazed surfaces of the building envelope are modeled using the following inputs:

- Glazing areas. Section 3.1.2A discusses determining the area of windows and skylights.
- Glazing orientation and slope. Section 3.1.2A discusses how slope affects window and skylight definitions.
- Glazing thermal conductance. Section 3.1.2I discusses how to determine the fenestration U-factor.
- Glazing solar heat gain coefficient. Section 3.1.2J discusses how to determine the solar heat gain coefficient of glazing.

Overhangs

Approved computer programs are able to model overhangs. Typical inputs are overhang projection, height above window, window height and the overhang horizontal extension past the edge of the window. If the overhang horizontal extension (past the window jambs) is not an input, then the program must assume that the extension is zero (i.e., overhang width is equal to window width) which results in no benefits from the overhang.

Interzone Surfaces

Heat transfer modeled through all surfaces separating different space conditioning zones may be modeled with inputs such as surface area, surface tilt and thermal conductance. Thermal mass characteristics may be modeled using the thickness, specific heat, density and types of layers that comprise the construction assembly.

3.2.5 Alterations

Alterations to the envelope of an existing conditioned space have the following options for showing compliance:

Option 1. Show that the overall heat gain and heat loss of the building is not increased. This can be demonstrated on form ENV-2, Overall Envelope Method, Part 2 of 6 and Part 3 of 6 by showing the heat gain and heat loss for the altered component(s) before and after the alteration; or

Option 2. Meet current prescriptive envelope requirements for the altered component; or

Note: The prescriptive solar heat gain coefficient requirements do not apply to fenestration repaired, replaced, or up to 50 square feet of new glass.

Option 3. Use an approved computer program to show compliance with an energy budget for the altered space; or

Option 4. Use an approved computer program to show that the energy use of the entire building is what it would be if the remainder of the building was unaltered and the altered space complied with its energy budget ("existing plus alteration"). This fourth option involves four steps and three separate computer runs:

Step 1. Model the building before any alterations or additions to determine the energy use of the existing building (use the value referred to as the "proposed" energy use).

Step 2. Model the new or altered space to determine the energy budget ("standard" design) of the alteration or addition alone.

Step 3. Calculate the energy budget for the entire building as indicated in Equation 3-6.

Equation 3-6– Energy Use Goal

$$\frac{(A_e \quad PD_e) \quad (A_a \quad SD_a)}{A_{e \quad a}} \quad \text{Energy Use Goal}$$

Where:

A_e = Area of the existing entire building before the proposed addition/alteration (from Step 1. above)

PD_e = Proposed design of the existing entire building before the proposed addition/alteration (from Step 1. above)

A_a = Area of the proposed addition/alteration (from Step 2. above)

SD_a = Standard design for the proposed addition/alteration (from Step 2, above)

A_{e+a} = Area of the entire building after the proposed addition/ alteration

Step 4. Model the entire building, including the proposed addition/ alteration, along with any improvements to the existing building. If the proposed design is less than or equal to the energy use goal (from Step 3. above), the addition or alteration complies.

Example 3-10– Existing-plus-Additions Approach

Question

3,000 ft^2 of conditioned space is being added to an existing office building. 60% of the lights in the existing office space are being replaced with more efficient fixtures. Can credit be taken for the improved lights in the existing building to comply through the existing-plus-addition performance approach?

Answer

Credit can only be taken for lighting efficiency improvements resulting in a lower lighting power density than is required to meet §146 of the standards. Otherwise, credit may be taken for improvement(s) to the envelope component *only*. Lighting in the existing building must meet all prescriptive requirements in this case (more than 50% of the lights replaced or the connected load is increased).

Example 3-11– NFRC Label Certificate Scenarios

Question

The envelope and space conditioning system of an office building with 120,000 ft^2 of conditioned floor area is being altered. The building has 24,000 ft^2 of vertical fenestration. Which of the following scenarios does the NFRC label certificate requirement apply to?

1. Existing glazing remains in place during the alteration.
2. Existing glazing is removed, stored during the alteration period and then re-installed (glazing is not altered in any way).
3. Existing glazing is removed and replaced with new site-assembled glazing with the same dimensions and performance specifications.
4. Existing glazing on the north façade (total area 6000 ft^2) is removed and replaced with site-assembled fenestration.

Answer

NFRC label certificate requirement does not apply to scenarios 1, 2, and 4 but does apply to scenario 3.

1. Requirement does not apply because the glazing remain unchanged and in place.
2. Exception to §116(a) applies in this case (this exception applies to fenestration products removed and reinstalled as part of a building alteration or addition).
3. Label certificate requirement applies in this case as 24,000 ft^2 (more than the threshold value of 10,000 ft^2) of new vertical fenestration is being installed in 120,000 ft^2 of conditioned floor area (more than the threshold value of 100,000 ft^2).
4. Label certificate requirements do not apply because less than 10,000 ft^2 of vertical glazing is being replaced.

3.3 Envelope Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the recommended forms and procedures for documenting compliance with the envelope requirements of the *Standards.* It does not describe the details of the requirements; these are presented in Section 3.2 Envelope Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the building department plan checkers who are examining documents for compliance with the *Standards.*

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections.

ENV-1: Certificate of Compliance
This form should be required for every job, and it is required to appear *on the plans. (Title 24, Part 1, §10-103 of the California Code of Regulations.)*

ENV-2: Envelope Component Method, Overall Envelope Method, or Performance Method
One of these three versions should be part of every envelope compliance submittal. Choose the version that corresponds to the compliance method selected for the job.

ENV-3: Metal-Framed Assembly, Masonry Assembly, or Proposed Wood Frame Assembly

One of these forms should be submitted for each construction assembly in the building that does not use an Energy Commission default U-factor. The version is chosen to match the type of assembly. If the assembly is something other than a metal-framed or masonry assembly, the Proposed Construction Assembly version of ENV-3 should be used.

Cool Roofs

Prior to January 1, 2003, manufacturer’s published performance data shall be acceptable to show compliance with minimum solar reflectance requirements for roofing products like concrete and clay tiles. Note that effective January 1, 2003 the label must be certified by the Cool Roof Rating Council (CRRC).

The performance data must include information on:

Test method

Date the test was performed

Thickness (mil) for liquid applied products

Solar reflectance

Thermal emittance

For liquid applied roofing products, the following key properties must also be tested:

Initial Tensile Strength

Initial Elongation

Elongation After 1000 Hours Accelerated Weathering

Permeance

Accelerated Weathering

Eligible tile cool roofs are roofs tested to have a solar reflectance of 0.4 or greater and a thermal emittance of 0.75 or greater (see 3.1.2H for details). Eligible single ply or liquid applied cool roofs are roofs tested to have a solar reflectance of 0.70 or greater and a thermal emittance of 0.75 or greater. Eligible liquid applied cool roofs will also have a thickness greater than 20 mils and meet minimum performance requirements.

3.3.1 ENV-1: Certificate of Compliance

The ENV-1 Certificate of Compliance form has two parts. Both parts must appear on the plans (usually near the front of the architectural drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the *Energy Commission's* forms), provided the information is the same and in similar format.

A. ENV-1 Part 1 of 2

Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

3. **PROJECT ADDRESS** is the address of the project as shown on the plans and known to the building department.

4. **PRINCIPAL DESIGNER - ENVELOPE** is the person responsible for the preparation of the building envelope plans, and who signs the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.

5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation and who signs the STATEMENT OF COMPLIANCE. The person's telephone number is given to facilitate response to any questions that arise.

6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

2. **BUILDING CONDITIONED FLOOR AREA** has specific meaning under the energy *Standards*. Refer to Section 2.2.1 for a discussion of this definition.

3. **CLIMATE ZONE** is the official climate zone number where the building is located. Refer to California Climate Zone Description (Appendix C) for a listing of cities and their climate zones.

4. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the *Nonresidential Standards* are designated "Nonresidential" here. It is possible for a building to include more than one building type, in which case check all applicable types here. See Section 2.2.1 for the formal definitions of these occupancies.

5. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2.2 for detailed discussion of the various choices.

   a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.2F), newly conditioned space (see Section 2.2.2B) or a stand-alone addition submitted for envelope compliance.

   b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses existing plus addition performance compliance, as described in Section 2.2.2E.

   c. **ALTERATION** should be checked for alterations to existing building envelopes. See Section 2.2.2D.

   d. **UNCONDITIONED** should be checked when the building is not intended as conditioned space, or when the owner chooses to defer demonstrating envelope compliance until such time as the space conditioning system permit application is submitted. See Section 2.2.2A for a full discussion. The building department may require the owner to file an affidavit declaring the building to be unconditioned and acknowledging that all the *Standards* requirements must be met when the building is conditioned.

6. **METHOD OF COMPLIANCE** - indicate which method is being used and documented with this submittal:

   a. **COMPONENT** for the Envelope Component Method

   b. **OVERALL ENVELOPE** for the Overall Envelope Method

   c. **PERFORMANCE** for the Performance Method

Statement of Compliance

The Statement of Compliance is signed by the person responsible for preparation of the plans for the building and the documentation author. This principal designer is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the *Business and Professions Code* (based on the edition in effect as of July 1998), referenced on the Certificate of Compliance are provided below:

5537. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person

Envelope Mandatory Measures

The Mandatory Measures should be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a note block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. A sample, generic envelope mandatory measures note block is shown in Example 3-12. This is offered as a starting point for designers; it should be incorporated into the organization of the plan set and modified to be specific to the building design.

Example 3-13– Sample Notes Block - Envelope Mandatory Measures

Installed Insulating Material

Shall have been certified by the manufacturer to comply with the California Quality Standards for Insulating Material.

All Insulating Materials

Shall be installed in compliance with the flame spread rating and smoke density requirements of Sections 2602 and 707 of the UBC.

All Exterior Joints

All Exterior joints and openings in the building envelope that are observable sources of air leakage shall be caulked, gasketed, weather-stripped or otherwise sealed.

Site Constructed Doors, Windows and Skylights

Shall be caulked between the unit and the building, and shall be weather-stripped (except for unframed glass doors and fire doors).

Manufactured Doors and Windows

Manufactured doors and windows installed shall have air infiltration rates certified by the manufacturer per §116(a)1. Manufactured fenestration products must be labeled for U-factor according to NFRC procedures.

Demising Wall Insulation

Demising wall insulation shall be installed with R-11 in all opaque portions of framed walls (except doors).

B. ENV-1 Part 2 of 2

The information on Part 2 summarizes the information about the building envelope that can be readily verified by the building department field inspector. This form should be included on the plans. Alternatively, the information may be incorporated into construction assembly and glazing schedules on the plans, provided it is complete and in substantially the same format as this form.

Opaque Surfaces

1. **SURFACE TYPE** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **CONSTRUCTION TYPE** - list the general type of construction for each opaque surface type. The entry should be descriptive, as it is used by the field inspector to distinguish between the various assemblies.

3. **AREA** - list the gross surface area of the surface type.

4. **U-FACTOR** - list the U-factor of the surface type.

5. **AZIMUTH** - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

6. **TILT** – Tilt of opaque surface is expressed in terms of degrees, 0=horizontal facing up, 90=vertical, 180=horizontal facing down.

7. **SOLAR GAINS Y/N** - indicate Y[yes] for opaque surfaces that will be receive direct or indirect sunlight.

8. **FORM 3 REFERENCE** - list the name used on the ENV-3 form for the proposed assembly (whether or not it is a default value).

9. **LOCATION/COMMENTS** - use to provide further description for each surface type. Again, it should be descriptive to assist in locating and inspecting the assembly.

10. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Site Assembled Glazing – Indicate by checking off box if building is greater than or equal to 100,000 sf^2 of CFA and greater than or equal to 10,000 sf^2. NFRC Certification is required. Follow NFRC 100-SB Procedures and submit NFRC Label Certificate form with submittal.

Fenestration Surfaces

1. **FENESTRATION TYPE** - provide a designator for each unique type of window.(e.g., window, skylight).

2. **AREA** - indicate the total square feet of all of the fenestration with the same characteristics.

3. **U-FACTOR** - indicate the maximum U-factor for windows using either manufacturer's data or the Energy Commission's default U-factors (See Section 3.1.2I).

4. **AZIMUTH** - the plan Azimuth is determined by an observer standing outside the building looking at the front elevation.

5. **SHGC** - list the solar heat gain coefficient (SHGC) of the fenestration product using either manufacturer's data or the Energy Commission's default SHGC values (see Table 3-12). Or use the alternative calculation procedure for Nonresidential Solar Heat Gain Coefficients (see Appendix B Table 12). This method is only used to calculate SHGC values. A SHGC center of glass alone value is required to be used with equations listed in Table 12. See 3.1.2J.

6. **GLAZING TYPE** - indicate the general type of primary glazing material for the window (clear, tinted, reflective, low-e, etc.).

7. **LOCATION/COMMENTS** - use to provide further description for each surface type. It should be descriptive enough to assist in locating and inspecting the fenestration.

8. **NOTE TO FIELD** - this column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance. There is additional space at the bottom of the form for more notes to the field inspector.

Exterior Shading

(Note that 'SHGC' and 'fins' apply to performance approach only).

1. **Fenestration** # - list the designation on the plans for the fenestration with exterior shading.

2. **Exterior Shade** Type - list the type of exterior shading, limited to devices permanently attached to the building (e.g., shade screens), or structural components of the building (i.e., overhangs and fins). Manually operable shading devices cannot be modeled.

3. **SHGC** - list the Solar Heat Gain Coefficient of the shading device. For Performance use only.

4. **Window** - when the shading type is an overhang or fin list the height and width (in feet) of the window.

5. **Overhang** - for overhangs being used to achieve compliance with prescriptive envelope requirements, list the dimensions (in feet) of the overhang:

   a. **Length** - is the distance (in feet) the overhang projects out from the building facade.

   b. **Height** - is the distance, in feet, from the bottom of the window to the bottom of the overhang. To qualify for credit, the bottom of the overhang must be no more than two vertical feet higher than the top of the window (window head).

LExt. and **RExt**. - is the length the overhang extends beyond the window on the left and right sides. Credit for an overhang may be taken only if the overhang extends beyond both sides of the window jamb a distance equal to the overhang length.

For Performance use only;

Left Fin – dimension which describes side fins to the left of the fenestration in feet-inches.

a. Distance along the wall from the left edge of the glazing. b. Length of the left fin from the wall, from the length field in the fins.

c. Height of the left fin from the bottom of the wall to the top of the fin.

Right Fin – dimension which describes side fins to the right of the fenestration in feet-inches.

a. Distance along the wall from the right edge of the glazing.

b. Length of the right fin from the wall, from the length field in the fins.

c. Height of the right fin from the bottom of the wall to the top of the fin.

Notes to Field

This space is for building department use only. It may be used by the plan checker to continue or elaborate on notes elsewhere on the form.

3.3.2 ENV-2: Envelope Component Method

This form (ENV-2) should be used only when the envelope is shown to comply using the Envelope Component Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Window Area Calculation

This calculation determines whether the window area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **GROSS WALL AREA** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits.

2. **DISPLAY PERIMETER** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 6 to determine the display perimeter area for glazing limits.

3. **MAXIMUM ALLOWABLE WINDOW AREA** - the greater of the previous two calculation results is the maximum window area allowed under the Envelope Component Method.

4. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowable Window Area, then the Envelope Component Method may not be used.

B. Skylight Area Calculation

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Envelope Component Method.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2A for definition and discussion.

2. **ALLOWED %** - Depending on the atrium height, the allowed percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - Gross roof area - refer to Section 3.1.2A for definition and discussion.

4. **ALLOWABLE SKYLIGHT AREA** - Allowed Skylight Area - the maximum allowable skylight area is the product of the previous two numbers.

5. **ACTUAL SKYLIGHT AREA** - Actual Skylight Area - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion. If this area is greater than the Maximum Allowed Skylight Area, then the Envelope Component Method may not be used.

C. Opaque Surfaces

1. **ASSEMBLY NAME** - provide a name or designator for each unique type of opaque surface. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

2. **TYPE** - provide the type of assembly as described in Table 3-22 and Table 3-23 (e.g. wood- frame wall, other floor/soffit, etc.). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly shown in Table B-7, e.g. R.30.2 x 10.16, in the "Opaque Surfaces" category.

3. **HEAT CAPACITY** - see Section 3.1.2G for discussion of how this value is found. For light-weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies, but if it is blank, the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

4. **INSULATION R-VALUE** - This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Assembly U-factor option is used, this space may be left blank. The PROPOSED value is the R-value for the insulation product alone, not the total R-value for the assembly. It must be consistent with the R-value called out on the ENV-1 form. The MIN. ALLOWED value is taken from Table 3-22 and Table 3-23.

5. **ASSEMBLY U-FACTOR** - This section is used for assemblies that are shown to comply by this option under the Envelope Component Method. If the Insulation R-value option is used, this space may be left blank. The PROPOSED value is taken either from an Energy Commission table of defaults, or is calculated on the appropriate ENV-3 (see Appendix B) and Sections 3.1.2C - F . If a default table value is used, check the “Y” (yes) box. If a calculated value is used, check the “N” (no) box and attach the corresponding ENV-3 form. The ALLOWED value is taken from Table 3-22 and Table 3-23.

D. Windows

1. **WINDOW NAME** - provide a name or designator for each unique type of window. This designator should be used consistently throughout the plan set (elevations, window schedules, etc.) to identify each window. It should also be consistently used on the other forms in the compliance documentation.

2. **ORIENTATION -** indicate orientation (see Section 3.1.2A for definitions) of each unique type of window. A window with an overhang and a similar window without an overhang would be different types. If overhangs are not used, similar windows on non-north orientations may be grouped together.

3. **U-FACTOR** - PROPOSED glazing U-factor is determined as discussed in Section 3.1.2I. ALLOWED U-factor is taken from Table 3-22 and Table 3-23.

4. **NO. OF PANES** - indicate “2” for double glazed, “1” for single glazed windows.

5. **PROPOSED RSHG** – indicate SHGC (Solar Heat Gain Coefficient), OHF (Overhang Factor), and the resulting RSHG (RSHG = SHGCwin x [1 + aH/V + b(H/V)^2]).

See Sections 3.1.2I and 3.1.2J. If given window does not have an overhang, then SHGC and RSHG are the same.

6. **ALLOW. RSHG** - the Maximum Relative Solar Heat Gain allowed, taken from Table 3-22 and Table 3-23, depending on the window orientation (north or non-north).

E. Skylights

1. **SKYLIGHT NAME** - provide a name or designator for each unique type of skylight. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each skylight. It should also be consistently used on the other forms in the compliance documentation.

2. **GLAZING** - indicate if glazing has curb or no curb. Indicate if the glazing is made of glass or plastic. This affects the allowed solar heat gain coefficient.

3. **NO. OF PANES** - indicate, “2” for double glazed, “1” for single glazed skylights.

4. **U-FACTOR** - PROPOSED glazing U-factor is determined as discussed in Section 3.1.2I. ALLOWED U-factor is taken from Table 3-22 and Table 3-23.

5. **SOLAR HEAT GAIN COEFFICIENT** - indicate PROPOSED solar heat gain coefficient. See Section 3.1.2J. The ALLOWED value is the Maximum Solar Heat Gain Coefficient taken from Table 3-22 and Table 3-23, depending on the type of glazing (made of glass or plastic).

3.3.3 ENV-2: Overall Envelope Method

This version of ENV-2 should be used only when the envelope is shown to comply using the Overall Envelope Method.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. ENV-2 Part 1 of 6

The first part of this form involves tests of glazing area for windows and skylights. If either of these tests does not pass, then the glazing area must be adjusted for the standard envelope.

Window Area Test

A. **DISPLAY PERIMETER** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 6 to determine the DISPLAY AREA for glazing limits.

B.-D. **GROSS EXTERIOR WALL AREA** - refer to Section 3.1.2A for definition and discussion. This is multiplied by 0.4 to determine the 40% area for glazing limits, and by 0.1 to determine the minimum area for glazing limits. The larger of the DISPLAY AREA and the 40% AREA is the MAXIMUM AREA.

E. **PROPOSED WINDOW AREA** - the total area of proposed windows shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculations, then the window area will be adjusted for the standard envelope. Otherwise, the window calculations on Parts 2 through 5 can be done without adjusted window or wall areas. Proceed to the SKYLIGHT AREA TEST.

1. or 2. **WINDOW ADJUSTMENT FACTOR** - if E is greater than D or less than C, one of these two calculations is done to obtain the WINDOW ADJUSTMENT FACTOR. This number is carried to Part 6 of the form to calculate the adjusted window and wall areas. Upon completion of those calculations, Part 2, Part 3, and Part 5 may be completed.

Skylight Area Test

This calculation determines whether the skylight area for the building exceeds the allowable maximum for the Standard Envelope.

1. **ATRIUM HEIGHT -** refer to Section 3.1.2A for definition and discussion.

2. **STANDARD %** - depending on the atrium height, the allowed standard percentage of roof area for skylights may be 5% (0.05) or 10% (0.1).

3. **GROSS ROOF AREA** - gross roof area - refer to Section 3.1.2A for definition and discussion.

4. **STANDARD SKYLIGHT AREA** - the maximum allowed standard skylight area is the product of the previous two numbers.

5. **PROPOSED SKYLIGHT AREA** - the total area of proposed skylights shown on the plans is entered here. See Section 3.1.2A for definition and discussion.

If it is necessary to proceed to the following calculation, then the skylight area will be adjusted for the standard envelope. Otherwise, the skylight calculations on Part 2, Part 3, and Part 5 can be done without the adjusted skylight or roof areas.

1. or 2. **SKYLIGHT ADJUSTMENT FACTOR** - this calculation is done to obtain the SKYLIGHT ADJUSTMENT FACTOR. This number is carried to Part 6 of the form to calculate the adjusted skylight and roof areas. Upon completion of those calculations, Parts 2 through 5 may be completed.

B. ENV-2 Part 2 of 6 Overall Heat Loss

This form should be used to confirm that the proposed envelope design has an overall heat loss no greater than the standard heat loss for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate “2” for double glazed, “1” for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2.A for definitions and discussion.

C. **PROPOSED HEAT CAPACITY -** see Section 3.1.2G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

D. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C - F and Sections 3.3.4 through 3.3.6).

TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

E. **PROPOSED UA** - the numbers in columns B and D are multiplied together and the result entered in this column.

F. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED

AREA for each assembly. If adjustments are required, then the adjusted areas of window, wall, skylight and roof are taken from Part 6.

G. **STANDARD U-FACTOR** - enter the Maximum U-factor for each assembly type, taken from Table 3-22 and Table 3-23*.* The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

H. **STANDARD UA** - the numbers in columns F and G are multiplied together and the result entered in this column.

Columns E and H are totaled and the results compared. If the Column E total is no greater than the Column H total, then the Overall Heat Loss requirement has been met.

C. ENV-2 Part 3 of 6 Overall Heat Gain from Conduction

This form should be used to confirm that the proposed envelope design has an overall heat gain from opaque surfaces no greater than the standard heat gain for the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of surface under the appropriate heading (WALLS, ROOFS/ CEILINGS, etc.). Demising walls are not to be included in this calculation. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. For windows and skylights, list the number of panes of glazing; indicate "2" for double glazed, "1" for single glazed windows.

B. **PROPOSED AREA** - enter the actual area, in square feet, of each assembly. Refer to Section 3.1.2A for definitions and discussion.

C. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and Climate Zone from Table 3-24 or *Standards* Table No. 1-J. For glass and skylight assume Light Mass.

D. **PROPOSED HEAT CAPACITY -** see Section 3.1.2.G for discussion of how this value is found. For light weight assemblies having HC less than 7.0 (most framed assemblies), this space may be left blank. It may also be left blank for higher heat capacity assemblies but if it is blank then the lower U-factor requirements for walls and floors/soffits with HC of 7.0 or higher may not be used.

E. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B, Sections 3.1.2C through 3.1.2F and Sections 3.3.4 through 3.3.6), or from EZ-FRAME output.

TABLE VALUES? - if the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, provide the "Reference Name" from the appropriate assembly type shown in Table B-7, e.g. R.30.2 x 10.16, in the "Roofs/Ceilings" and "Floors/Soffits" categories under the "Assembly Name" column of Form ENV-2 Part 2 "Overall Envelope Method". Enter the "Assembly Name" as instructed in the form, followed by the "Reference Name".

F. **HEAT GAIN Q** - the numbers in columns B, C and E are multiplied together and the result entered in this column.

G. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 6.

H. **STANDARD U-FACTOR** - enter the Maximum U-factor for each assembly type, taken from Table 3-22 and Table 3-23*.* The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

I. **TEMPERATURE FACTOR** - enter the temperature factor based on the envelope type and climate zone from Table 3-24 or *Standards* Table No. 1-J. For glass and skylight assume Light Mass.

J. **HEAT GAIN Q** - the numbers in columns G, H and I are multiplied together and the result entered in this column.

Columns F and J are totaled and the results compared. These subtotals are entered under 'Part 3 Subtotal' in columns I and M of ENV-2 Part 5 of 6.

D. ENV-2 Part 4 of 6 Overall Heat Gain from Radiation

This form should be used to confirm that the proposed envelope design has an overall heat gain no greater than the standard heat gain for the opaque surfaces of the building.

A. **ASSEMBLY NAME** - provide a name or designator for each unique type of roof surface (e.g., Roof-1, Roof-2, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. **AREA** - enter the actual area, in square feet, of each assembly. Refer to 3.1.2A for definitions and discussion

C. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

D. **WEIGHTING FACTOR** - enter the appropriate weighting factor based on climate zone and weighting factors. $WFG_{G,}$ for glazing, $WF_{R,}$ for roof and $WF_{S\ for}$ skylight, each

E. **PROPOSED U-FACTOR** - enter the U-factor of the proposed assembly as designed. U-factors are taken either from an Energy Commission table of defaults, or are calculated on the appropriate ENV-3 (see Appendix B)

F. **PROPOSED ABSORPTIVITY** ( )- Enter the absorptivity of the proposed roof assembly (use an absorptivity of 0.45 for cool roofs and an absorptivity of 0.7 for all other roofs).

G. **PROPOSED HEAT GAIN** - the numbers from columns B, C, D, E, and F are multiplied and entered in this column.

H. **AREA (ADJUSTED)** - if no skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each roof assembly. If adjustments are required, then the adjusted areas of skylight and roof are taken from Part 6.

I. **STANDARD U-FACTOR** - enter the Maximum U-factor for each roof assembly, taken from Table 3-22 and Table 3-23. The selected value may depend upon the type of construction or the heat capacity of the assembly. These are determined in the same way as under the Envelope Component Approach, as described in Section 3.2.2.

J. **STANDARD ABSORPTIVITY** ( )-Enter the absorptivity of the standard roof assembly (0.70).

K. **STANDARD HEAT GAIN -** multiply columns C, D, H, I, and J and enter the result here.

Columns G and K are totaled. These subtotals are entered under 'Part 4 Subtotal' in columns I and M of ENV-2 Part 5 of 6.

E. ENV-2 Part 5 of 6 Overall Heat Gain from Radiation

This form should be used to confirm that the proposed envelope design has an overall heat gain no greater than the standard heat gain for fenestration for the building and summarizes the heat gain from opaque surfaces and fenestration.

A. **WINDOW/SKYLIGHT NAME** - provide a name or designator for each orientation of glazing under the appropriate heading (NORTH, SOUTH, SKYLIGHTS, etc.). This designator should be used consistently throughout the plan set (elevations, roof plans, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B. **WEIGHTING FACTOR** - enter the weighting factor for each orientation and skylight. The weighting factors are taken from Table 3-25 or *Standards* Table No. 1-K*,* and depend on the climate zone (from ENV-1, Part 1).

C. **PROPOSED AREA** - the total area of proposed windows and skylights shown on the plans is entered here. See Section 3.1.2A for definitions and discussion.

D. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

E. **PROPOSED SHGC** - the proposed solar heat gain coefficient of the glazing. See Section 3.1.2J.

F.-H. **PROPOSED OVERHANG** - indicate the overhang horizontal length (H), the overhang vertical height (V); overhang ratio (H/V); and overhang factor (OHF). Column F includes both (H for horizontal) and (V for vertical). See Section 3.1.2N. The overhang adjustment does not apply to skylights.

I. **PROPOSED TOTAL** - multiply columns B, C, D, E & H and enter the result here.

J. **STANDARD AREA** - if no window or skylight area adjustments are required (as demonstrated on Part 1), then the STANDARD AREA is the same as the PROPOSED AREA for each window and skylight. If adjustments are required, then the adjusted areas are taken from Part 6.

K. **STANDARD RSHG** - this is the Maximum Relative Solar Heat Gain (RSHG) taken from Table 3-22 and Table 3-23 depending on the window orientation (north or non-north). The Maximum Solar Heat Gain Coefficient (SHGC) for skylights is taken from the same table, depending on whether the skylight glazing is made of glass or plastic. Note skylight must use SHGC and RSHG value is not allowed.

L. **SOLAR FACTOR** - enter the solar factor for the applicable climate zone from Table 3-24 or *Standards* Table No. 1-J.

M. **STANDARD TOTAL -** multiply columns B, J, K & L and enter the result here.

Columns I and M are totaled, Totals from Columns F and J from Part 3 of 6 and Part 4 of 6 are carried forward and added, and the results compared. If the Column I total is no greater than the Column M total, then the Overall Heat Gain requirement has been met.

F. ENV-2 Part 6 of 6 Window Area Adjustment Calculations

This form should be included with all compliance submittals. If the WINDOW AREA TEST or the SKYLIGHT AREA TEST (Part 1 of this form) determines that area adjustments are not necessary, check the NOT APPLICABLE boxes. If the tests indicate that adjustments must be made, perform the calculations in the appropriate sections below.

A. **WALL NAME** - provide a name or designator for each unique type and orientation of wall that contains windows (walls without windows will have no adjustment). If an orientation has two different wall types, list each separately. This designator should be used consistently throughout the plan set (elevations, finish schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation. See Section 3.1.2A for a discussion of orientation.

B.-D. **AREAS** - list the areas (in square feet). See 3.1.2A for definitions of these areas. The GROSS AREA is the Gross Exterior Wall Area for the particular wall type and orientation under consideration. The DOOR AREA and WINDOW AREA are for doors and windows included in each wall.

E. **WINDOW ADJUSTMENT FACTOR** is calculated on the top half of Part 1. It is the same for all windows in the building.

F. **ADJUSTED WINDOW AREA** is calculated by multiplying the values in Columns D and E.

G. **ADJUSTED WALL AREA** is calculated by subtracting B from the sum of C and F. If this produces a negative value enter zero.

Add Columns B, C, D, F and G. As a check, the total of Column B should equal the sum of the totals of Columns F & G.

The total in Column G is used in Column F of the Overall Heat Loss calculation (Part 2) and Column I of the Overall Heat Gain from Conduction calculation (Part 3) and the values in Column F are used in Column G of the Overall Heat Gain from Radiation calculation (Part 5).

Skylight Area Adjustment Calculations

A. **ROOF NAME** - provide a name or designator for each unique type of roof that contains skylights (roofs without skylights will have no adjustment). If an orientation has two different roof types, list each separately. This designator should be used consistently throughout the plan set (roof plans, skylight schedules, etc.) to identify each surface. It should also be consistently used on the other forms in the compliance documentation.

B.-C. **AREAS** - list the areas (in square feet). See Section 3.1.2A for definitions of these areas. The GROSS AREA is the Gross Exterior Roof Area for the particular roof type and orientation under consideration; note that it does not include doors, such as roof hatches. The SKYLIGHT AREA is for skylights included in each roof.

D. **SKYLIGHT ADJUSTMENT FACTOR** is the Skylight Adjustment Factor calculated on the bottom half of Part 1. It is the same for all skylights in the building.

E. **ADJUSTED SKYLIGHT AREA** is calculated by multiplying the values in columns C and D.

F. **ADJUSTED ROOF AREA** is calculated by subtracting E from B. If this results in a negative value enter zero.

Columns B, C, E and F are added. As a check, the total of Column B should equal the sum of the totals of Columns E and F.

The totals in Columns E and F are used in Column F of the Overall Heat Loss calculation (Part 2) and in Column G of the Overall Heat Gain from Conduction calculation (Part 3), and the values in Column E are used in Column I of the Overall Heat Gain from Radiation calculation (Part 5).

3.3.4 ENV-3: Proposed Metal Framed Assembly

For most metal framed assemblies, the U-factor will be found in Table B-2 in Appendix B (see Section 3.1.2E for a discussion of the use of this table). When there is no appropriate U-factor in Table B-2, then this version of ENV-3 should be used to calculate the assembly U-factor.

[Note that this form is not used to describe metal furring systems for insulating masonry or concrete walls; these are described in ENV-3 Masonry Assemblies.]

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note that the outside of the assembly, facing unconditioned space, is at the left.

2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.

3. **ASSEMBLY TYPE** - check the appropriate box.

4. **FRAMING MATERIAL** - must be metal for this form (other versions of ENV-3 are for other framing materials).

5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 3 1/2", 5 1/2", or other appropriate description.

6. **INSULATION R-VALUE** - enter the R-value of the insulation material in the assembly. If there is more than one insulation material, list each separately.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the wall that does not contain framing members) is calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.
2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer. This value is taken from manufacturers' literature or from the *ASHRAE Handbook of Fundamentals Volume, 1993,* Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials.* The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.
3. **METAL FRAMING FACTOR (MFF)** - enter the appropriate value for the assembly from Table 3-3 (Appendix B, Table B-3), or the table on the form.
4. **Rc X MFF** - multiply the SUBTOTAL R-value (R_c) for the cavity by the METAL FRAMING FACTOR and enter the result.
5. **INSULATING SHEATHING -** if there is a layer of insulating sheathing (other than the cavity insulation between the framing members), enter its R-value. Only values from *ASHRAE Handbook of Fundamentals Volume, 1993,* Table 3a, Chapter 23, may be used.
6. **TOTAL R-VALUE (R_t)** - add the previous two numbers and enter the result here.
7. **ASSEMBLY U-FACTOR** - divide 1 by the TOTAL R-VALUE (R_t) to obtain the ASSEMBLY U-FACTOR.

COMMENTS may be added to further explain the assembly or its U-factor calculation. This would be especially helpful for unusual assemblies, and could help to expedite plan checking for energy compliance.

3.3.5 ENV-3: Proposed Masonry Wall Assembly

This version of ENV-3 should be used for masonry wall assemblies (including concrete block, brick and solid concrete). It is used in conjunction with Tables B-4 and B-5 in Appendix B, which give U-factors and heat capacities for most common assemblies. It should also be used to account for the insulating qualities of insulating sheathing and/or furred sheathing layers attached to the masonry. Refer to Section 3.1.2F for further description of these calculations.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of any furring members and sheathing layers should be apparent. Note that the outside of the assembly, facing unconditioned space, is at the left.

2. **WALL ASSEMBLY NAME** - list the name or designator for this wall assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, or some other naming convention appropriate to the construction document organization.

3. **DESCRIPTION OF ASSEMBLY** - provide a brief description of the materials used in the assembly to augment the sketch.

B. Wall R-value and Heat Capacity

This section is used to extract values of wall R-value and heat capacity from Tables B-4 or B-5 in Appendix B.

1. **WALL UNIT THICKNESS** - enter the nominal thickness, in inches, of the masonry wall.

2. **MATERIAL TYPE** - enter the material type. For concrete block, this can be “light weight”, “medium weight”, or “normal weight” as per ASTM designations.

3. **CORE TREATMENT** - this is only applicable to hollow core masonry units; the choices are solid grouted cores, or partially grouted cores with the unfilled cells either empty or filled with any type of insulation.

4. **WALL R-VALUE (R_w)** - for hollow masonry, use Table B-4; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate R-value and enter it here (see Section 3.1.2F for more discussion).

5. **WALL HEAT CAPACITY (HC)** - for hollow masonry, use Table B-5; for solid unit masonry or solid concrete walls, use Table B-5. Select the appropriate HC value and enter it here (see Section 3.1.2G for more discussion).

C. Furring/Insulation Layer

This section is used to describe any furring/insulation layers or insulating sheathing attached to either the inside or the outside of the masonry.

1. **FURRING FRAMING MATERIAL** - list the type of material (wood, metal) used for the furring strips; if not applicable enter "none".

2. **FURRING FRAMING SIZE** - enter the thickness, width, and depth, in actual inches, of the framing members used for furring, and its actual dimensions in inches.

3. **FURRING SPACE INSULATION** - enter the type of insulation installed in the space between furring strips (fiberglass batt, bead board, etc.), and its R-value at the installed thickness.

4. **EXTERIOR INSULATING LAYER** - if there is an exterior insulating layer, list the type of insulation (bead board, polyisocyanurate board, etc.), and its R-value at the installed thickness.

5. **FURRING ASSEMBLY EFFECTIVE R-VALUE** - using the information above, enter Table B-6 and locate the effective R-value of the furring assembly (see Section 3.1.2F).

6. **INSULATION LAYER R-VALUE (R_f)** - add the FURRING ASSEMBLY EFFECTIVE R-VALUE to the R-value of the exterior insulating layer to arrive at the INSULATION LAYER R-VALUE (R_f).

D. Wall Assembly R-value and U-factor

1. **WALL ASSEMBLY R-VALUE (R_t)** - add the INSULATION LAYER R-VALUE calculated above (R_t) to the WALL R-VALUE (R_w) from above to obtain the WALL ASSEMBLY R-VALUE.

2. **WALL ASSEMBLY U-FACTOR** - calculate the inverse of the WALL ASSEMBLY R-VALUE ($1/R_t$) to obtain the WALL ASSEMBLY U-FACTOR.

3.3.6 ENV-3: Proposed Wood Frame Assembly

This version of ENV-3 should be used for any construction assembly that is not found in the tables in Appendix B or appropriate for the metal framed or masonry versions of ENV-3. This form guides the user through the basic U-factor calculation, the Parallel Path Method (discussed in Section 3.1.2D), and the heat capacity calculation (see Section 3.1.2G). If the proposed wood-framed wall, floor or ceiling assembly is one of the Standard Framed Wall/Floor/Ceiling Assembly types shown in Table B-7 of Appendix B, it is not necessary to submit Form ENV-3 "Proposed Construction Assembly". Instead, the "Reference Name" for the appropriate assembly is entered into either Form ENV-2 "Envelope Component Method" or ENV-2 Part 2 "Overall Envelope Method", whichever is applicable for the compliance method that the designer has selected. Refer to the specific sections in the Manual which provide instructions for filling out the respective forms, as to how the Reference Name of the assembly should be entered.

1. **PROJECT NAME** is the title of the project, as shown on the plans, on the ENV-1, and as known to the building department.

2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

A. Component Description

1. **SKETCH OF ASSEMBLY** - provide a simple cross-section sketch showing the arrangement of components in the assembly. The position of framing members and layers should be apparent. Number the layers in sequence from outside to inside as they will be described below (framing members are not numbered, only the cavity layers are considered here). Note the outside of the assembly, facing unconditioned space, is at the left of the sketch.

2. **ASSEMBLY NAME** - list the name or designator for this assembly as it is referred to on the plans and on the other compliance forms in the submittal, e.g. WALL-1, ROOF-2, or some other naming convention appropriate to the construction document organization.

3. **ASSEMBLY TYPE** - check the appropriate box.

4. **FRAMING MATERIAL** - with this form framing material is wood only (other versions of ENV-3 are for other materials).

5. **FRAMING SIZE** - enter the nominal dimensions of the framing members, e.g. 2x4, 4x8, or other appropriate description.

6. **FRAMING PERCENTAGE** - choose the appropriate value from the small table to the right. For example, a floor assembly with joists spaced 24" on center (o.c.) would have a framing percentage of 7%.

B. Construction Components

In this part of the form, the R-value of the cavity (the area of the assembly that does not contain framing members) and the R-value of the assembly through the wood framing are calculated. The U-factor of the assembly is also calculated.

1. **DESCRIPTION** - list each layer of the assembly in sequence, from outside to inside, as numbered in the sketch above.

2. **CAVITY R-VALUE (R_c) -** enter the R-value of each layer at a cross-section taken through the cavity. This value is taken from manufacturer's literature or from *the ASHRAE Handbook of Fundamentals Volume, 1993,* (Chapter 22, Table 4, *Typical Thermal Properties of Common Building and Insulating Materials*) data reproduced in Appendix B, Table B-1. The R-values for the INSIDE and OUTSIDE SURFACE AIR FILMS are taken from Table 3-1, Standard Air Film R-values.

3. **WOOD FRAME R-VALUE (R_f)** - enter the R-value of each layer at a cross-section taken through a framing member. These values are found in the same sources cited in the previous paragraph.

4. **HEAT CAPACITY (HC) -** As an option, the HC of the assembly may also be calculated, although for most framed assemblies the HC will be too low to be of significance (HC values of less than 7 are not given any special consideration under the *Standards*).

5. **WALL WEIGHT -** enter the weight of each layer of the assembly, per square foot of the material at its given thickness. This is calculated from the density of the material, which is given in pounds per cubic foot. They may be taken from manufacturers literature or other standard reference works, such as the *ASHRAE Handbook of Fundamentals Volume, 1993*, Chapter 22 Table 4 (Appendix B). Dividing the density by 12 and multiplying by the material thickness (in inches) yields the WALL WEIGHT. For the framing material, the weight of the framing members must be converted to a pounds per square foot value.

6. **SPECIFIC HEAT** - enter the specific heat of each material, in Btu/°F-lb. These values are also found in ASHRAE Table 4 (see previous paragraph).

7. **HC** - columns A and B are multiplied together to obtain the heat capacity for each layer of the assembly.

8 **SUBTOTALS** - both R-value columns are summed. If calculated, the HC column is also summed to obtain the TOTAL HC for the assembly.

9. **ASSEMBLY U-FACTOR** - the appropriate values from above on this form are entered into the equation and the result calculated. Rc is the subtotal of the CAVITY R-VALUE column; R_f is the subtotal of the WOOD FRAME R-VALUE column. Fr% is the FRAMING PERCENTAGE. Care should be taken to recognize the parentheses in the calculation.

3.4 Envelope Inspection

The envelope building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the ENV-1 Certificate of Compliance, or a similar form, that must be printed on the plans (see Section). Included on the ENV-1 are “Notes to Field” which are provided by the plan checker to alert the inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I. Fenestration May require inspection of labels or label certificates. See Section 3.1.2M

4 Mechanical Systems

4.0 Summary

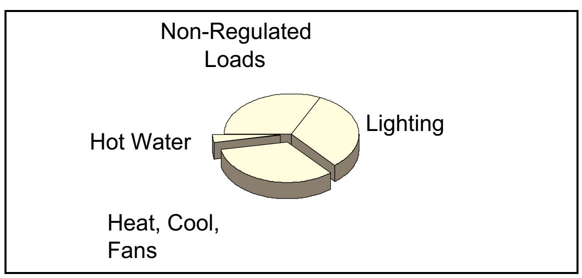
This chapter summarizes the requirements for space conditioning, ventilating, and service water-heating systems. Section 4.1 introduces the approaches to mechanical system compliance with the Energy Efficiency Standards (*Standards*) and mechanical system concepts. The Mechanical Design Procedures, (Section 4.2), covers the mandatory, prescriptive and performance requirements for mechanical systems. For the convenience of designers, a summary of the most important requirements for many of the major heating, ventilating, and air conditioning (HVAC) systems types is included at the end of this section. The Mechanical Plan Check section (Section 4.3), describes the information that must be included in the building plans and specifications to show compliance with the *Standards*, including a presentation and discussion of the mechanical compliance forms. The Mechanical Inspection section (Section 4.4) refers to the Inspection Checklist in Appendix I identifying the items that the inspector will verify in the field.

4.1 Introduction

Mechanical systems are the second largest consumer of energy in most buildings, exceeded only by lighting. The proportion of space-conditioning energy consumed by various mechanical components varies according to system design and climate. For most buildings in non-mountainous California climates, fans or cooling equipment may be the largest consumer of energy. Space-heating energy is usually less than fans and cooling, followed by service water heating.

Figure 4-1– Typical Building Energy Use

(Energy Efficiency Report, October 1990, California Energy Commission Publication No. 400-90-003)



The objective of the *Standards* requirements for mechanical systems is to reduce energy consumption while maintaining occupant comfort. These goals are achieved by:

1. Maximizing equipment efficiency, both at design conditions and during part load operation
2. Minimizing distribution losses of heating and cooling energy
3. Optimizing system control to minimize unnecessary operation and simultaneous usage of heating and cooling energy

The *Standards* also recognize the importance of indoor air quality for occupant comfort and health. To this end, the *Standards* incorporate requirements for outdoor air ventilation that must be met during all operating conditions.

4.1.1 Mechanical Compliance Approaches

After the mandatory measures are met, the *Standards* allow mechanical system compliance to be demonstrated through prescriptive or performance requirements.

Mandatory Measures (§110-119 and §120-129) apply to all systems, whether the designer chooses the prescriptive or performance approach to compliance. Mandatory measures include:

1. Certification of equipment efficiency
2. Ventilation requirements
3. Demand ventilation controls
4. Thermostats, shut-off control and night setback/setup
5. Area isolation
6. Duct work construction and insulation
7. Pipe insulation
8. Service water heating and pool heating

Prescriptive Measures cover items that can be used to qualify components and systems on an individual basis and are contained in §144. Prescriptive measures provide the basis for the *Standards* and are the prescribed set of measures to be installed in a building for the simplest approach to compliance. Prescriptive measures include:

1. Load calculations, sizing, system type and equipment selection (§144(a) and (b))
2. Fan power consumption (§144(c))
3. Controls to reduce reheating, recooling and mixing of conditioned air streams; supply air reset; and variable air volume (VAV) box minimum position (§144(d) and (f))
4. Economizers (§144(e))
5. Restrictions on electric-resistance heating (§144(g))
6. Fan speed controls for heat rejection equipment (§144(h))

The *Performance* approach (§141) allows the designer to increase the efficiency or effectiveness of selected mandatory and prescriptive measures, and to decrease the efficiency of other prescriptive measures. The performance approach requires the use of an *Energy Commission* certified computer program, and may only be used to model the performance of mechanical systems that are covered under the building permit application. (See Sections 2.2 and 6.1 for more detail.)

4.1.2 Basic Mechanical Concepts

This section presents definitions and key concepts that apply to mechanical systems. Definitions in italics are quoted from §101(b). Other definitions and concepts are not officially part of the *Standards*, but are included here as an aid in understanding the sections that follow.

A. Definitions of Efficiency

§111-§112 mandate minimum efficiency requirements that regulated appliances and other equipment must meet. These efficiency requirements are listed in Table B-9 in

Appendix B. The following describes the various measurements of efficiency used in the *Standards*.

The purpose of space-conditioning and water-heating equipment is to convert energy from one form to another, and to regulate the flow of that energy. Efficiency is a measure of how effectively the energy is converted or regulated. It is expressed as the ratio:

Equation 4-1

$$Efficiency \quad \frac{Output}{Input}$$

The units of measure in which the input and output energy are expressed may be either the same or different, and vary according to the type of equipment. The *Standards* use several different measures of efficiency.

Annual Fuel Utilization Efficiency (AFUE) *is a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated during a year, as determined using the applicable test method in the Appliance Efficiency Regulations or §112.* The AFUE is usually lower than thermal efficiency because it takes into account the effects of equipment cycling or modulation at loads than design. It is calculated using a prescribed annual load profile.

Coefficient of Performance (COP)**, Cooling**, *is the ratio of the rate of net heat removal to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or §112*.

Equation 4-2

$$COP = \frac{Cooling\ Output\ Btu / hr}{Electric\ Input\ Btu / hr}$$

As electricity is normally measured in Watts, electric input must be converted to Btu/hr.

Coefficient of Performance (COP)**, Heating**, *is the ratio of the rate of net heat output to the rate of total energy input, calculated under designated operating conditions and expressed in consistent units, as determined using the applicable test method in the Appliance Efficiency Regulations or §112.*

Equation 4-3

$$COP \quad \frac{Heating\ Output\ Btu / hr}{Electric\ Input\ Btu / hr}$$

Combustion Efficiency is not defined in the *Standards*, but is used as the efficiency measurement for large boilers and service water heaters. It is a measure of the percent of energy transfer from the fuel to the heat exchanger (HX). Input and output energy are expressed in the same units so that the result has nondimensional units:

Equation 4-4

$$\%\ Combustion\ Eff = \frac{Energy\ to\ HX}{Total\ Fuel\ Input}$$

Note: *Combustion efficiency does not include losses from the boiler jacket. It is strictly a measure of the energy transferred from the products of combustion.*

Energy Efficiency Ratio (EER) *is the ratio of net cooling capacity (in Btu/hr) to total rate of electrical energy (in watts), of a cooling system under designated operating conditions, as determined using the applicable test method in the Appliance Efficiency Regulations or §112*. An EER is typically used for larger packaged air conditioning equipment to express equipment efficiency

Equation 4-5

$$EER = \frac{Cooling\ Btu / hr}{Electric\ Input\ Watts}$$

EER and COP are actually measurements of the same process, but are expressed in different units. They are related as:

Equation 4-6

$$COP = \frac{EER}{3.413}$$

Energy Factor (EF) *is the ratio of energy output to energy consumption of a water heater, expressed in equivalent units, under designated operating conditions over a 24-hour use cycle, as determined using the applicable test method in the Appliance Efficiency Regulations.* It includes both the thermal efficiency of the heating process, as well as standby losses.

Fan Power Index is the power consumption of the fan system per cubic feet of air moved per minute.

Integrated Part Load Value (IPLV) *is a single number of merit based on part load EER or COP expressing part load efficiency for air-conditioning and heat-pump equipment on the basis of weighted operation at various load capacities for the equipment as determined using the applicable test method in the Appliance Efficiency Regulations or §112* . It is meant to approximate the 'typical' or annual operating efficiency of the equipment, much as an AFUE is used for heating equipment.

Seasonal Energy Efficiency Ratio (SEER) *means the total cooling output of a central air conditioner in British thermal units during its normal usage period for cooling divided by the total electrical energy input in watt-hours during the same period, as determined using the applicable test method in the Appliance Efficiency Regulations.*

Thermal Efficiency is defined in the Appliance Efficiency Regulations as a measure of the percentage of heat from the combustion of gas which is transferred to the water as measured under test conditions specified. This definition applies to gas water heaters. In the *Standards*, this definition is generalized to include warm air furnaces.

Equation 4-7

$$\%\ Thermal\ Eff = \frac{Energy\ to\ Medium}{Total\ Fuel\ Input}$$

B. Definitions of Spaces and Systems

The concepts of spaces, zones, and space-conditioning systems are discussed in this subsection.

Fan System is a fan or collection of fans that are used in the scope of the Prescriptive requirement for fan-power limitations (§144(c)). §144(c) defines fan-systems as all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors. For cooling systems this includes supply fans, return fans, relief fans, fan coils, parallel-style fan powered boxes and exhaust fans. For systems without cooling this includes supply fans, return fans, relief fans, fan coils, series-style fan powered boxes, parallel-style fan powered boxes and exhaust fans. Parallel-style fan-powered boxes are not included in a cooling fan system as the fans are normally only operated during heating. Series-style fan-powered boxes are included in both heating and cooling fan systems as they operate during both normal cooling and heating.

Space is not formally defined in the *Standards*, but is considered to be an area that is physically separated from other areas by walls or other barriers. From a mechanical perspective, the barriers act to inhibit the free exchange of air with other spaces. The term "space" may be used interchangeably with "room."

Zone, Space Conditioning *is a space or group of spaces within a building with sufficiently equivalent comfort conditioning requirements so that comfort conditions, as specified in §144(b)3 or §150(h), as applicable, can be maintained throughout the zone by a single controlling device.* It is the designer's responsibility to determine the zoning; in most cases each building exposure will consist of at least one zone. Interior spaces that are not affected by outside weather conditions usually can be treated as a single zone.

A building will generally have more than one zone. For example, a facility having 10 spaces with equivalent conditioning that are heated and cooled by a single space-conditioning unit using one thermostat, is one zone. However, if a second thermostat and control damper, or an additional mechanical system, is added to separately control the temperature within any of the 10 spaces, then the building has two zones.

The term **Space-Conditioning System** is used to define the scope of *Standard* requirements. It is a catch-all term for mechanical equipment and distribution systems that *provide either collectively or individually- heating, ventilating, or cooling within or associated with conditioned spaces in a building.* HVAC equipment is considered part of a space-conditioning system if it does not exclusively serve a process within the building. Space conditioning systems include general and toilet exhaust systems.

Space-conditioning systems may encompass a single HVAC unit and distribution system (such as a package HVAC unit) or include equipment that services multiple HVAC units (such as a central outdoor air supply system, chilled water plant equipment or central hot water system).

C. Types of Air

Exhaust Air is air being removed from any space or piece of equipment and conveyed directly to the atmosphere by means of openings or ducts. The exhaust may serve specific areas, such as toilet rooms, or may be for a general building relief, such as an economizer.

Make-up Air is air provided to replace air being exhausted.

Mixed Air is a combination of supply air from multiple air streams. The term *mixed air* is used in the Standard in an exception to the Prescriptive requirement for Space Conditioning Zone Controls (§144(d)). In this manual the term mixed air is also used to describe a combination of outdoor and return air in the mixing plenum of an air handling unit.

Outdoor Air (Outside Air) *is air taken from outdoors and not previously circulated in the building.* For the purposes of ventilation, outdoor air is used to flush out pollutants produced by the building materials, occupants and processes. To ensure that all spaces are adequately ventilated with outdoor air, the *Standards* require that each space be adequately ventilated (see Section 4.2.1C).

Return Air is air from the conditioned area that is returned to the conditioning equipment either for reconditioning or exhaust. The air may return to the system through a series of ducts, or through plenums and airshafts.

Supply Air is air being conveyed to a conditioned area through ducts or plenums from a space-conditioning system. Depending on space requirements, the supply may be heated, cooled, or neutral.

Transfer Air is air that is transferred directly from either one space to another or from a return plenum to a space. Transfer air is a way of meeting the ventilation requirements at the space level and is an acceptable method of ventilation per Standard §121. It works by transferring air with a low level of pollutants (from an over ventilated space) to a space with a higher level of pollutants (see Section 4.2.1E). The concept of ventilation through transfer air is also supported by ASHRAE Standard 62-1999.

D. Air Delivery Systems

Space-conditioning systems can be grouped according to how the airflow is regulated.

Constant Volume System is a space-conditioning system that delivers a fixed amount of air to each space. The volume of air is set during the system commissioning.

Variable Air Volume (VAV) System *is a space conditioning system that maintains comfort levels by varying the volume of conditioned air to the zones served.* This system delivers conditioned air to one or more zones. There are two styles of VAV systems, single-duct VAV where mechanically cooled air is typically supplied and reheated through a duct mounted coil, and dual-duct VAV systems where heated and cooled streams of air are blended at the zone level. In single-duct VAV systems the duct serving each zone is provided with a motorized damper that is modulated by a signal from the zone thermostat. The thermostat also controls the reheat coil. In dual-duct VAV systems the ducts serving each zone are provided with motorized dampers that blend the supply air based on a signal from the zone thermostat.

Pressure Dependent VAV Box has an air damper whose position is controlled directly by the zone thermostat. The actual airflow at any given damper position is a function of the air static pressure within the duct. Because airflow is not measured, this type of box cannot precisely control the airflow at any given moment: a pressure dependent box will vary in output as other boxes on the system modulate to control their zones.

Pressure Independent VAV Box has an air damper whose position is controlled on the basis of measured airflow. The setpoint of the airflow controller is, in turn, reset by a zone thermostat. A maximum and minimum airflow is set in the controller, and the box modulates between the two according to room temperature.

E. Attics and Return Plenums

Attics are unoccupied, unconditioned space located above the conditioned spaces, and outside of the insulated building envelope. Attics are usually closer to outdoor temperature than conditioned space temperature.

Return Air Plenum is an unoccupied space within the insulated building envelope through which air flows back to the space-conditioning system from the space(s). Return plenums are normally immediately above a ceiling, and below an insulated roof or the floor above. The return air temperature is usually within a few degrees of space temperature.

F. Zone Reheat, Recool and Air Mixing

When a space-conditioning system supplies air to one or more zones, different zones may be at different temperatures because of varying loads. Temperature regulation is normally accomplished by varying the conditioned air supply (variable volume), by varying the temperature of the air delivered, or by a combination of supply and temperature control. With multiple zone systems, the ventilation requirements or damper control limitations may cause the cold air supply to be higher than the zone load, this air is tempered through reheat or mixing with warmer supply air to satisfy the actual zone load. The Standard Prescription §144(c) limits the amount of energy used to simultaneously heat and cool the same zone as a basis of zone temperature control

[**Zone**] **Reheat** *is the heating of air that has been previously cooled by cooling equipment or systems or an economizer.* A heating device, usually a hot water coil, is placed in the zone supply duct and is controlled via a zone thermostat. Electric reheat is sometimes used, but is severely restricted by the *Standards*.

[**Zone**] **Recool** *is the cooling of air that has been previously heated by space conditioning equipment or systems serving the same building.* A chilled water or refrigerant coil is usually placed in the zone supply duct and is controlled via a zone thermostat. Recooling is less common than reheating.

Zone Air Mixing occurs when more than one stream of conditioned air is combined to serve a zone. This can occur at the HVAC system (e.g. multizone), in the ductwork (e.g. dual-duct system) or at the zone level (such as a zone served by a central cooling system and baseboard heating). In some multizone and dual duct systems an unconditioned supply is used to temper either the heating or cooling air through mixing. The Standard Prescriptive §144(c) only applies to systems that mix heated and cooled air.

G. Economizers

Air Economizer is a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical cooling [during mild or cool weather].

When the compliance path chosen for meeting the Standards requires an economizer, the economizer must be integrated into the system so that it is capable of satisfying part of the cooling load while the rest of the load is satisfied by the refrigeration equipment. The operation of an integrated air economizer is diagrammed in Figure 4-2. When outdoor air is sufficiently cold, the economizer satisfies all cooling demands on its own. As the outdoor temperature (or enthalpy) rises, or as system cooling load increases, a point may be reached where the economizer is no longer able to satisfy the entire cooling load. At this point the economizer is supplemented by mechanical refrigeration, and both operate concurrently. Once the outside drybulb temperature (for temperature controlled economizer) or enthalpy (for enthalpy economizers) exceeds that of the return air or a predetermined high limit, the outside air intake is reduced to the minimum required, and cooling is satisfied by mechanical refrigeration only.

Nonintegrated economizers cannot be used to meet the economizer requirements of the prescriptive compliance approach. In nonintegrated economizer systems, the economizer may be interlocked with the refrigeration system to prevent both from operating simultaneously. The operation of a nonintegrated air economizer is diagrammed in Figure 4-3. Nonintegrated economizers can only be used if they comply through the performance approach.

Figure 4-2– Integrated Air Economizer

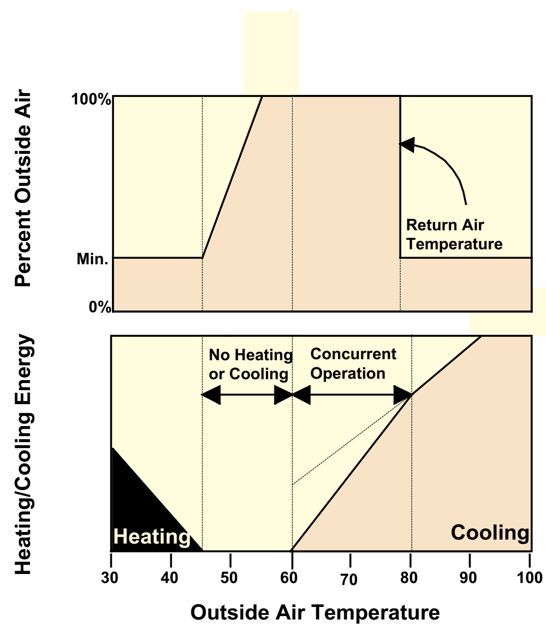
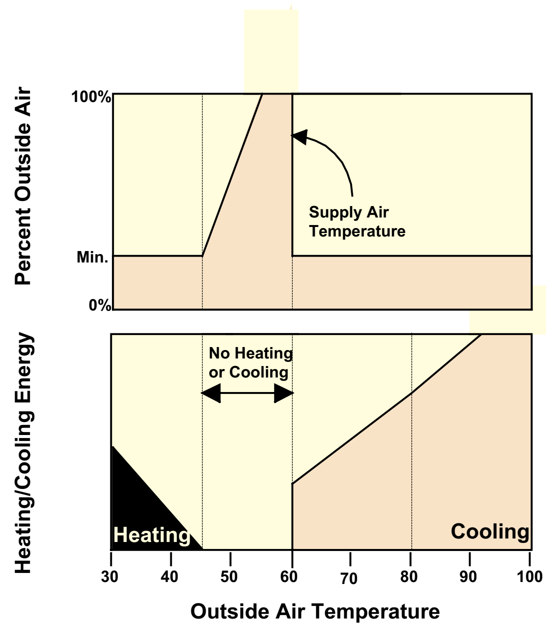


Figure 4-3– Non-integrated Air Economizer



Water Economizer is a system by which the supply air of a cooling system is cooled indirectly by evaporation of water in order to reduce or eliminate the need for mechanical cooling.

As with an air economizer, a water economizer must be integrated into the system so that the economizer can supply a portion of the cooling concurrently with the refrigeration system.

There are three common types of water-side economizers:

1. "Strainer-Cycle" or Chiller-Bypass Water Economizer. This system, depicted in Figure 4-4 below, does *not* meet the prescriptive requirement, as it cannot operate in parallel with the chiller. This system is applied to equipment with chilled water coils.

2. Water-precooling Economizer. This system depicted in Figure 4-5 and Figure 4-6 below *does* meet the prescriptive requirement if properly sized. This system is applied to equipment with chilled water coils.

3. Air-precooling Water Economizer. This system depicted in Figure 4-7 below *also meets* the prescriptive requirement if properly sized. The air-precooling water economizer is appropriate for water-source heat pumps and other water-cooled HVAC units.

To comply with the prescriptive requirements, the cooling tower serving a water-side economizer must be sized for 100% of the anticipated cooling load at the off-design outdoor-air condition of 50°Fdb/45°Fwb. This requires rerunning the cooling loads at this revised design condition and checking the selected tower to ensure that it has adequate capacity.

Figure 4-4– "Strainer Cycle" Water Economizer

This system does not *meet the prescriptive requirement, as it cannot operate in parallel with the chiller*

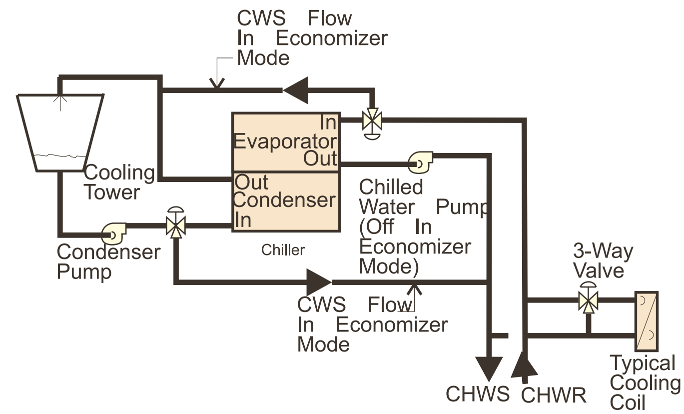


Figure 4-5– Water-Precooling Water Economizer with Three-Way Valves

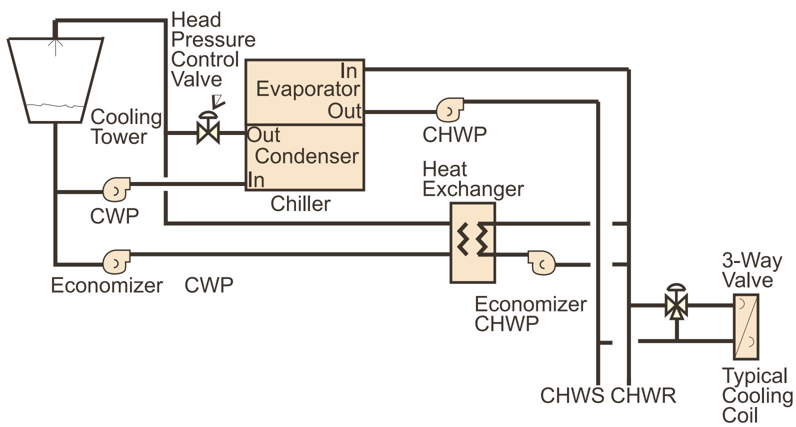


Figure 4-6– Water-Precooling Water Economizer with Two-Way Valves

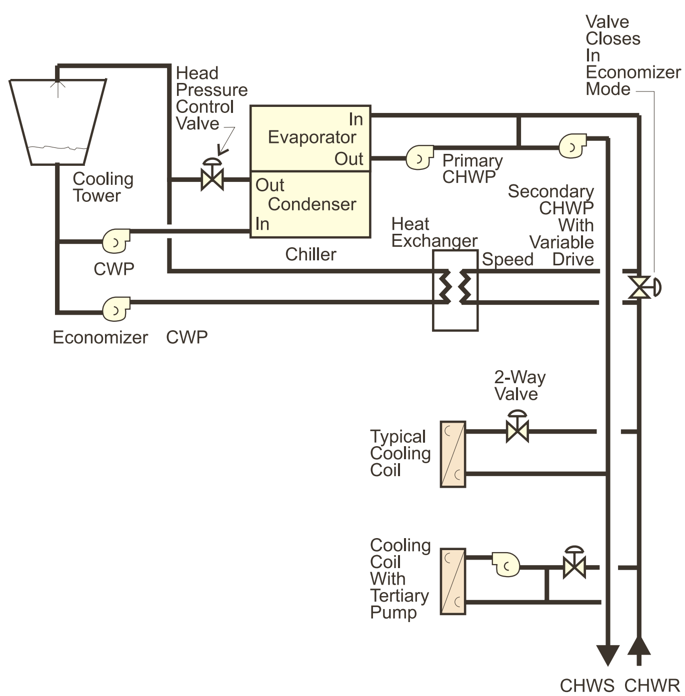
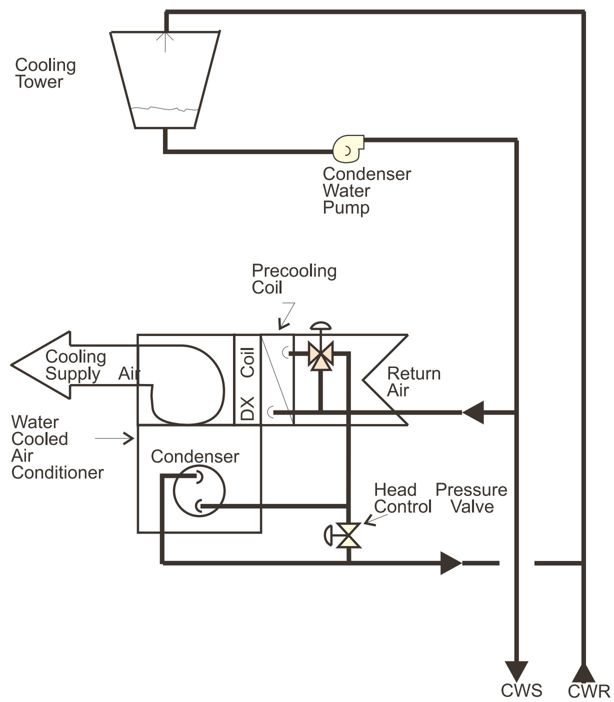


Figure 4-7– Air-Precooling Water Economizer



H. Unusual Sources of Contaminants

§121 addresses ventilation requirements for buildings and uses the term of "unusual sources of contamination." In this context, such contaminants are considered to be chemicals, materials, processes or equipment that produce pollutants which are considered harmful to humans, and are not typically found in most building spaces. Examples may include some cleaning products, blueprint machines, heavy concentrations of cigarette smoke and chemicals used in various processes.

The designation of such spaces is left to the designer's discretion, and may include considerations of toxicity, concentration and duration of exposure. For example, while photocopiers and laser printers are known to emit ozone, scattered throughout a large space it may not be of concern. A heavy concentration of such machines in a small space may merit special treatment (See Section 4.2.1C).

I. Demand Control Ventilation

Demand control ventilation is required for use on systems which *primarily serve areas with fixed seating and occupant densities less than or equal to 10 square foot per person, or identified in Chapter 10 of the UBC as either "Assembly Areas, Concentrated Use (without fixed seats)" or "Auction Rooms"* (§121(c)3) and that have a design outdoor air rate equal to or exceeding 3,000 cfm. Demand control ventilation is also allowed as an exception in the ventilation requirements for intermittently occupied systems (§121(c)1, §121(c)3 and §121(c)4). It is a concept in which the amount of outdoor air used to purge one or more offending pollutants from a building is a function of the measured level of the pollutant(s).

§121 allows for any demand control ventilation device that is approved by the Commission. The most common device employs the carbon dioxide (CO_2) sensor. Carbon dioxide sensors measure the level of carbon dioxide, which is used as a proxy for the amount of pollutant dilution in densely occupied spaces. CO_2 sensors have been on the market for many years and are available with integrated self-calibration devices that maintain a maximum guaranteed signal drift over a 5-year period. ASHRAE Standard 62

-1999 provides some guidelines on the application of demand control ventilation, including Appendix D of the ASHRAE Standard.

Demand ventilation controls are available at either the system level (used to reset the minimum position on the outside air damper) and at the zone level (used to reset the minimum airflow to the zone). The zone level devices are sometimes integrated into the zone thermostat.

J. Intermittently Occupied Spaces

The demand control ventilation devices discussed above are allowed and/or required only in spaces that are intermittently occupied. An intermittently occupied space is considered to be an area that is infrequently or irregularly occupied by people. Examples include auction rooms, movie theaters, auditoriums, gaming rooms, bars, restaurants, conference rooms and other assembly areas. Because the standard requires base ventilation requirement in office spaces that are very close to the actual required ventilation rate at 15 cfm per person, these controls may not save significant amounts of energy for these low-density applications. However, even in office applications, some building owners may install CO_2 sensors as a way to monitor ventilation conditions and alert to possible malfunctions in building air delivery systems.

4.2 Mechanical Design Procedures

4.2.1 Mandatory Measures

The Mandatory Requirements for mechanical equipment must be included in the system design whether compliance is shown by the Prescriptive or the Performance Approach. These features have been shown to be cost effective over a wide range of building types and mechanical systems.

It is worth noting that many of the mandatory features and devices, such as equipment efficiency, are requirements of the manufacturer. It is the responsibility of the designer, however, to specify products in the building design that meet these requirements.

Mechanical equipment subject to the Mandatory Requirements must:

1. Be certified by the manufacturer as complying with the efficiency requirements as prescribed in:

   §111 Appliances regulated by the Appliance Efficiency Regulations;

   §112 Space Conditioning;

   §113 Service Water Heating Systems and Equipment;

   §114 Pool and Spa Heating systems and Equipment;

   §115 Pilot Lights Prohibited

2. Be specified and installed in accordance with:

   §121 Requirements for Ventilation;

   §122 Required Controls for Space Conditioning Systems;

   §123 Requirements for Pipe Insulation;

   §124 Requirements for Ducts and Plenums.

A. Equipment Certification (§111-113)

Mechanical equipment installed in a building subject to these regulations must be certified as meeting certain minimum efficiency and control requirements. These requirements are contained in the Appliance Efficiency Regulations, and are also listed in Appendix B, Table B-9. The AFUE, COP, EER, IPLV, Combustion Efficiency, and Thermal Efficiency values of all equipment must be determined using the applicable test method specified in the Appliance Efficiency Regulations, §112, or §113:

1. Where more than one efficiency standard or test method is listed, the requirements of both shall apply. For example, both an EER and IPLV are listed for water-cooled air conditioners. This means that the air conditioner must have a rated EER equal to or higher than that specified at Air-Conditioning and Refrigeration Institute (ARI) standard rating conditions, and must also have an annual IPLV equal to or higher than that specified using ARI's assumed operating profiles (§112(a)1 & 2 and §113(b)1 & 2).
2. Where equipment can serve more than one function, such as both heating and cooling, or space heating and water heating, it must comply with the requirements applicable to each function.
3. Where a requirement is for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the capacity shall be as provided for and allowed by the

controls during steady state operation. For example, a boiler with Hi/Lo firing must meet the efficiency requirements when operating at both its maximum capacity and minimum capacity (§112(a)4 and §113(b)4).

4. Small appliances such as room air conditioners, gas space heaters and small water heaters, are regulated through the Appliance Efficiency Regulations found in Title 20, Chapter 2, Subchapter 4, Article 4 of the California Code of Regulations. To comply, manufacturers must certify to the *Energy Commission* that their equipment meets minimum standards.
5. Electric water-cooled centrifugal chillers that are not designed for operation at the ARI Standard 550-1992 or 590-1992 test conditions of 44°F chilled water supply and 85°F condenser water supply must comply with the modified efficiency levels in *Standards* Tables 1-C8, 1-C9, and 1-C10 shown as Tables B-9H through B-9K in Appendix B. Many water-cooled centrifugal chillers designed for the moderate climates of California cannot operate stably at the ARI test conditions. The manufactures can provide ARI certified performance data at these adjusted conditions upon request.
6. Evaporatively cooled chillers shall meet the efficiency requirements as shown in Appendix B, Table B-9C for air-cooled chillers of the same compressor type.
7. The equipment in *Standards* Tables 1-C1 through 1-C7 and Table 1-C11 have two separate sets of requirements. The first set is titled, *Efficiency Prior to 10/29/2001*. The second set is titled, *Efficiency as of 10/29/2001*. As stated in Standard §112(a)5 and §113(b)5, this date relates to the date of manufacture for the equipment. Equipment manufactured prior to 10/29/2001 complies with the Standard if it meets the requirements in the *Efficiency Prior to 10/29/2001* column even if it is purchased and/or installed after 10/29/2001 (See 4-3).

Example 4-1– Efficiency Compliance

Question

If a gas-pack with 15 tons cooling and 260,000 Btu/hr maximum heating capacity has an EER = 9.6 and a heating efficiency of 78 percent, does it comply?

Answer

No. The cooling side complies because the EER exceeds the requirements. The cooling requirements from Table 1-C1 of the Standard (see Appendix B, Table B-9) require an EER of 9.7 for units with electric resistance heat and 9.5 for units with all other heating sections. With gas heat and an EER of 9.6 this unit complies. Note that the 0.2 deduction provided in the efficiency tables 1-C1 and 1-C2 compensate for the higher fan power required to move air over the heat exchangers for fuel fired heaters.

The heating efficiency must be at least 80 percent; therefore the unit does not comply (see Appendix B Table B-9).

Example 4-2– Efficiency Compliance

Question

A 500,000 Btu/hr gas-fired boiler with Hi/Lo firing has a full load combustion efficiency of 82 percent, and a Lo-fire combustion efficiency of 80 percent. Does the unit comply?

Answer

Yes. The combustion efficiency is at least 80 percent at both, the maximum- and minimum-rated capacity (see Appendix B, Table B-9).

Example 4-3– Efficiency Compliance

Question

A 10 ton rooftop heat pump manufactured in 1995 has been in storage and is to be installed in a building that begins construction in 2002. What are the required cooling efficiencies?

Answer

The date of manufacture is prior to 10/29/2001. The appropriate efficiencies from Standard Table 1-C2 (Appendix B, Table B-9) are 8.9 EER and 8.3 IPLV.

Example 4-4– Efficiency Compliance

Question

A 300 ton centrifugal chiller is designed to operate at 44°F chilled water supply, 80°F condenser water supply and 3 gpm/ton condenser water flow, what is the required COP and IPLV?

Answer

As the chiller is centrifugal and is designed to operate at a condition different from ARI Standard 550/590, the appropriate efficiencies can be found in Standard Table 1-C9 (Appendix B, Table B-9). This chiller must have a COP and IPLV greater than or equal to 5.97 at the design conditions.

Example 4-5– Efficiency Compliance

Question

A 300 ton centrifugal chiller is designed to operate at 45°F chilled water supply, 82°F condenser water supply and 94°F condenser water return, what is the required COP and IPLV?

Answer

As the chiller is centrifugal and is designed to operate at a condition different from ARI Standard 550/590, the appropriate efficiencies can be found in *Standard* Table 1-C9 (Appendix B, Table B-9). The conditions for this chiller are in between values in Table 1-C9. The equation in the footnotes of the table can be used to find the required COP and IPLV as follows:

LIFT=Tcws-Tchws=82°F -45°F =37°F

Condenser DT=Tcwr-Tcws=94°F -82°F =12°F

X=LIFT+Condenser DT=37°F+12°F=49°F

Kadj=6.1507-0.30244*X + 0.0062692*(X^2) - 0.000045595*(X^3)=1.019

COPadj= IPLVadj=Kadj*COPstd=1.019*5.55=5.66

This chiller must have a COP and IPLV greater than or equal to 5.66 at the design conditions. Note this number could also have been calculated through interpolation from precalculated table values.

Larger equipment not covered by the Appliance Efficiency Regulations is regulated by §112 and §113 of the *Standard*. To comply, equipment specified in the plans and specifications must meet the minimum standards mandated in that section. Manufacturers of equipment not regulated by the Appliance Efficiency Regulations are not required to certify their equipment to the *E*nergy Commission; it is the responsibility of the designer and contractor to specify and install equipment that complies.

Control Equipment Certification (§119(d) & §121(c)1)

In addition to the mechanical equipment discussed above, the following control devices must be certified to the *E*nergy *Commission* prior to specification or use:

1. **Occupancy Sensors** - per §119(d).
2. **Demand Controlled Ventilation** Devices - per §121(c)4.

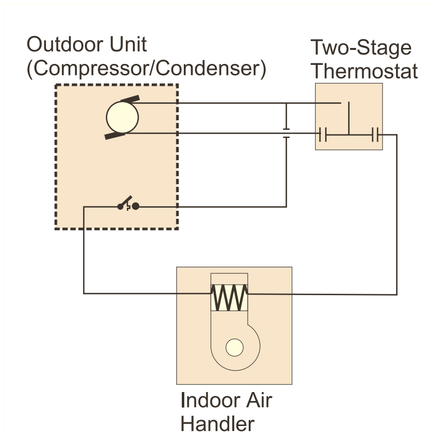
Note: *Automatic time switches must meet the requirements of §119(c). When used solely for mechanical controls they are not required to be certified.*

B. Heat Pump Controls (§112b)

Heat pumps with electric resistance supplemental heaters must have controls that limit the operation of the supplemental heater to defrost and as a second stage of heating when the heat-pump alone cannot satisfy the load. The most effective solution is to specify an electronic thermostat designed specifically for use with heat pumps. This "anticipatory" thermostat can detect if the heat pump is raising the space temperature during warm-up fast enough to warrant locking out the auxiliary electric resistance heater.

This requirement can also be met using conventional electronic controls with a two-stage thermostat and an outdoor lockout thermostat wired in series with the auxiliary heater. The outdoor thermostat must be set to a temperature where the heat pump capacity is sufficient to warm up the space in a reasonable time (e.g. above 40°F). This conventional control system is depicted schematically in Figure 4-8 below.

Figure 4-8– Heat Pump Auxiliary Heat Control Using Two-Stage and Outdoor Air Thermostats



C. Furnace Standby Loss Controls (§112c)

Forced air gas- and oil-fired furnaces with input ratings   225,000 Btu/h are required to have controls and designs that limit their standby losses:

1. They must have either an intermittent ignition or interrupted device (IID). Standing pilot lights are not allowed.
2. They must have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the conditioned space.

Any furnace with an input rating   225,000 Btu/h that is not located within the conditioned space must have jacket losses not exceeding 0.75% of the input rating. This includes electric furnaces as well as fuel-fired units.

D. Pilot Lights (§115)

Pilot lights are prohibited in:

1. Pool and spa heaters (§114(a)5).

2. Household cooking appliances unless the appliance does not have an electrical connection, and the pilot consumes less than 150 Btu/hr (§115(b)).

3. Fan type central furnaces. This includes all space-conditioning equipment that distributes gas-heated air through duct work (§115(a)). This prohibition does not apply to radiant heaters, unit heaters, boilers or other equipment that does not use a fan to distribute heated air.

E. Outdoor Ventilation - General Requirements (§121)

Ventilation Scope

Within a building all enclosed spaces that are normally used by humans must be continuously ventilated during occupied hours with outdoor air using either natural or mechanical ventilation (§121(a)1).

Note: The *Standards* highly recommend that spaces that may have unusual sources of contaminants be designed with enclosures to contain the contaminants, and local exhaust systems to directly vent the contaminants outdoors (§121(a)1).

The designation and treatment of such spaces is subject to the designer's discretion. Spaces needing special consideration may include:

- Commercial and coin-operated dry cleaners
- Bars and cocktail lounges
- Smoking lounges and other designated smoking areas
- Beauty and barber shops
- Auto repair workshops
- Print shops, graphic arts studios and other spaces where solvents are used in a process
- Copy rooms, laser printer rooms or other rooms where it is expected that equipment may generate heavy concentrations of ozone or other contaminants

"Spaces normally used by humans" refers to spaces where people can be reasonably expected to remain for an extended period of time. Spaces where occupancy will be brief and intermittent, and that do not have any unusual sources of air contaminants, do not need to be directly ventilated. For example:

1. A **closet** does not need to be ventilated provided it is not normally occupied.
2. A **storeroom** that is only infrequently or briefly occupied does not require ventilation. However, a storeroom that can be expected to be occupied for extended periods for clean-up or inventory must be ventilated, preferably with systems controlled by a local switch so that the ventilation system operates only when the space is occupied.

F. Natural Ventilation (§121(b)1)

Natural outdoor ventilation may be provided for spaces where all areas of the space are within 20 feet of an operable wall or roof opening through which outdoor air can flow. The sum of the areas of the openings must total at least 5 percent of the floor area of each space that is naturally ventilated. The openings must also be readily accessible to the occupants of the space at all times.

Airflow through the openings must come directly from the outdoors; air may not flow through any intermediate spaces such as other occupied spaces, unconditioned spaces, corridors, or atriums. High windows or operable skylights should be accessible from the floor.

Example 4-6– Natural Ventilation

Question

What is the window area required to ventilate a 30' x 32' classroom?

Answer

In order for all points to be within 20 feet of an opening, windows must be evenly divided between two opposing walls. The area of the openings must be:

(32 feet x 30 feet) x 5% = 48 square feet

The actual window area must be at least 96 square feet if only half the window can be open at a time.

Calculations must be based on free area, taking into account framing, the actual window area is approximately 100 square feet.

Example 4-7– Natural Ventilation

Question

Naturally ventilated classrooms are located on either side of a doubly-loaded corridor and transoms are provided between the classrooms and corridor. Can the corridor be naturally ventilated through the classrooms?

Answer

No. The corridor cannot be naturally ventilated through the classrooms and transom openings. The *Standard* requires that naturally ventilated spaces have direct access to properly sized openings to the outdoors. The corridor would require mechanical ventilation using either supply or exhaust fans.

G. Mechanical Ventilation (§121(b)2 and (d))

Mechanical outdoor ventilation must be provided for all spaces normally occupied that are not naturally ventilated. The standard requires that a space conditioning system provide outdoor air equal to or exceeding the ventilation rates required for each of the spaces that it serves. At the space the required ventilation can be provided either directly through supply air or indirectly through transfer of air from the plenum or an adjacent space. The required minimum ventilation airflow at the space can be provided by an equal quantity of supply and/or transfer air.

Each *space* requiring mechanical ventilation shall be provided with outdoor air at a design rate that is the greater of the two methods listed below. The rates specified by these methods are summarized in Table 4-1A. Ventilation rates must be the greater of either:

Table 4-1A - Minimum Ventilation Rates

Type of Use	CFM / SF Conditioned Floor Area
Auto Repair Workshops	1.50
Barber Shops	0.40
Bars, Cocktail Lounges, and Casinos	1.50
Beauty Shops	0.40
Coin-Operated Dry Cleaning	0.30
Commercial Dry Cleaning	0.45
High Rise Residential	Per UBC Section 1203
Hotel Guest Rooms (< 500 sf)	30 CFM per Guest Room
Hotel Guest Rooms (> or = 500 sf)	0.15
Retail Stores	0.20
Smoking Lounges	1.50
All Others	0.15

1. The **conditioned floor area of the space**, multiplied by the applicable minimum ventilation rate from Table 4-1A (*Standard* Table 1-F).

2. 15 cfm per person, multiplied by the expected number of occupants. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants as determined in accordance with Chapter 10 of the Uniform Building Code (UBC) is the number of fixed seats. For spaces without fixed seating, the expected number of occupants is assumed to be no less than one-half the maximum occupant load assumed for exiting purposes in Chapter 10 of the UBC. Table 4-1B shows the typical maximum occupant loads for various building uses upon which minimum ventilation calculations are based.

Each *space-conditioning system* must provide outdoor ventilation air as follows. It should be noted that systems employing demand ventilation controls as approved by the *Energy Commission* may provide lower quantities of ventilation air during periods of low occupancy:

1. For a space-conditioning system serving a single space, the required system outdoor air flow is equal to the design outdoor ventilation rate of the space.

2. For a space-conditioning system serving multiple spaces, the required outdoor air quantity delivered by the space-conditioning system must be not less than the sum of the required outdoor ventilation rate to each space. The *Standards* do not require that each space actually receive its calculated outdoor air quantity (§121(b)2 Exception.) Instead, the actual supply to any given space may be any combination of recirculated air, outdoor air, or air transferred directly from other spaces, provided:

a. The total amount of outdoor air delivered by the space-conditioning system(s) to all spaces is at least as large as the sum of the space design quantities

b. Each space always receives a supply airflow, including recirculated air and/or transfer air, no less than the calculated outdoor ventilation rate

c. When using transfer air, none of the spaces from which air is transferred has any unusual sources of contaminants

Table 4-1B - UBC 1997 Occupant Densities (ft² /person)

USE / APPLICATION	*OCCUPANT LOAD FACTOR*	*USE / APPLICATION*	*OCCUPANT LOAD FACTOR*
Aircraft Hangars	*500*	*Courtrooms*	*40*
Auction Room	*7*	*Dormitories*	*50*
ASSEMBLY AREAS		*Dwellings*	*300*
Auditoriums	*7*	*Garage Parking*	*200*
Churches/Chapels	*7*	*Healthcare Facilities*	
Lobbies	*7*	*Sleeping Rooms*	*120*
Lodge Rooms	*7*	*Treatment Rooms*	*240*
Reviewing Stands	*7*	*Hotel/Apartments*	*200*
Stadiums	*7*	*Kitchens - Commercial*	*200*
Waiting Areas	*3*	*Library*	
Conference Room	*15*	*Reading Rooms*	*50*
Dining Rooms	*15*	*Stack Areas*	*100*
Drinking Rooms	*15*	*Locker Room*	*50*
Exhibit Rooms	*15*	*Malls (see UBC chpt.4)*	*--*
Gymnasiums	*15*	*Manufacturing Areas*	*200*
Lounges	*15*	*Mechanical Equipment Rooms*	*300*
Stages	*15*	*Day Care*	*35*
Gaming: Keno, Slot Machine and Live Games Area	*11*	*Offices*	*100*
		School Shops/Vocational Rooms	*50*

Bowling Alley (assume no occupants for lanes)	*5/alley+15ft runway*	*Skating Rinks*	*50 Skate Area/ 15 on Deck*
Children's Home	*80*	*Storage/Stock Rooms*	*300*
Home for Aged	*80*	*Stores – Retail Sales Room*	
Classrooms	*20*	*Basements and Ground Floor*	*30*
Congregate Residences Accommodating 10 or less persons and having an area of 3,000 sq.ft. or less	*200*	*Upper Floors*	*60*
		Swimming Pools	*50 Pool Area/ 15 on Deck*
		Warehouses	*500*
		All Others	*100*

Table 4-2 - Required Minimum Ventilation Rate Per Occupancy

Occupancy / Use			UBC Table No. 10-A		Choose Largest		
			Sf/ Occupant	Number of People per 1000 ft²	Ventilation CEC STD Table 1-F CFM/ft²	UBC Based Ventilation CFM/ft²	Req. Vent CFM/ft² (largest)
1)	Aircraft Hangars		500	2	0.15	0.02	0.15
2)	Auction Rooms		7.0	143	0.15	1.07	1.07
3)	Assembly Areas (Concentrated Use)						
		Auditoriums	7.0	143	0.15	1.07	1.07
		Bowling Alleys	4.0	250	0.15	1.88	1.88
		Churches & Chapels (Religious Worship)	7.0	143	0.15	1.07	1.07
		Dance Floors	7.0	143	0.15	1.07	1.07
		Lobbies	7.0	143	0.15	1.07	1.07
		Lodge Rooms	7.0	143	0.15	1.07	1.07
		Reviewing Stands	7.0	143	0.15	1.07	1.07
		Stadiums	7.0	143	0.15	1.07	1.07
		Theaters - All	7.0	143	0.15	1.07	1.07
		Waiting Areas	3.0	333	0.15	2.50	2.50
4)	Assembly Areas (Nonconcentrated Use)		15.0	67	0.15	0.50	0.50
		Conference & Meeting Rooms (1)	15.0	67	0.15	0.50	0.50
		Dining Rooms/Areas	15.0	67	0.15	0.50	0.50
		Drinking Establishments (2)	15.0	67	1.50	0.50	1.50
		Exhibit/Display Areas	15.0	67	0.15	0.50	0.50
		Gymnasiums/Sports Arenas	15.0	67	0.15	0.50	0.50
		Lounges	15.0	67	1.50	0.50	1.50
		Stages	15.0	67	1.50	0.50	1.50

		Gaming, Keno, Slot Machine and Live Games Areas	11.0	91	1.50	0.68	1.50
5)	Auto Repair Workshops		100.0	10	1.50	0.08	1.50
6)	Barber & Beauty Shops		100.0	10	0.40	0.08	0.40
7)	Children's Homes & Homes for Aged		80.0	13	0.15	0.09	0.15
8)	Classrooms		20.0	50	0.15	0.38	0.38
9)	Courtrooms		40.0	25	0.15	0.19	0.19
10)	Dormitories		50.0	20	0.15	0.15	0.15
11)	Dry Cleaning (Coin-Operated)		100.0	10	0.30	0.08	0.30
12)	Dry Cleaning (Commercial)		100.0	10	0.45	0.08	0.45
13)	Garage, Parking		200.0	5	0.15	0.04	0.15
14)	Healthcare Facilities:	Sleeping Rooms	120.0	8	0.15	0.06	0.15
		Treatment Rooms	240.0	4	0.15	0.03	0.15
15)	Hotels and Apartments		200.0	5	0.15	0.04	0.15
		Hotel Function Area (3)	15.0	67	0.15	0.50	0.50
		Hotel Lobby	100.0	10	0.15	0.08	0.15
		Hotel Guest Rooms (<500 ft²)	200.0	5	Footnote 4	Footnote 4	Footnote 4
		Hotel Guest rooms (>=500 ft²)	200.0	5	0.15	0.04	0.15
		High-rise Residential	200.0	5	Footnote 5	Footnote 5	Footnote 5
16)	Kitchen(s)		200.0	5	0.15	0.04	0.15
17)	Library :	Reading Rooms	50.0	20	0.15	0.15	0.15
		Stack Areas	100.0	10	0.15	0.08	0.15
18)	Locker Rooms		50.0	20	0.15	0.15	0.15
19)	Manufacturing		200.0	5	0.15	0.04	0.15
20)	Mechanical Equipment Room		300.0	3	0.15	0.03	0.15
21)	Nurseries for Children - Day Care		50.0	20	0.15	0.15	0.15
22)	Offices:	Office	100.0	10	0.15	0.08	0.15
		Bank/Financial Institution	100.0	10	0.15	0.08	0.15
		Medical & Clinical Care	100.0	10	0.15	0.08	0.15
23)	Retail Stores (See Stores)						
24)	School Shops & Vocational Rooms		50.0	20	0.15	0.15	0.15
25)	Skating Rinks:	Skate Area	50.0	20	0.15	0.15	0.15
		On Deck	15.0	67	0.15	0.50	0.50
26)	Stores :	Retail Sales, Wholesale Showrooms	30.0	33	0.20	0.25	0.25
		Basement and Ground Floor	30.0	33	0.20	0.25	0.25

	Upper Floors	60.0	17	0.20	0.13	0.20
	Grocery	30.0	33	0.20	0.25	0.25
	Malls, Arcades, & Atria	30.0	33	0.20	0.25	0.25
27)	Swimming Pools : Pool Area	50.0	20	0.15	0.15	0.15
	On Deck	15.0	67	0.15	0.50	0.50
28)	Warehouses, Industrial & Commercial Storage/Stockrooms (see 4.2.1 b) 4.24.2.1D)	500.0	2	0.15	0.02	0.15
29)	All Others -- Including Unknown	100.0	10	0.15	0.08	0.15
	Corridors, Restrooms, & Support Areas	100.0	10	0.15	0.08	0.15
	Commercial & Industrial Work	100.0	10	0.15	0.08	0.15

Footnotes:

1) Convention, Conference, Meeting Rooms

2) Bars, Cocktail & Smoking Lounges, Casinos

3) See Conference Rooms or Dining Rooms

4) Guestrooms less than 500 ft² use 30 cfm/guestroom

5) High-rise Residential See 1994 UBC Section 1203 Ventilation

Equations used to find:

1) Number of People per 1000sf = $\frac{1000}{\text{Sf/Occupant}}$

2) UBC Based Ventilation CFM/ft² =

$$\frac{\frac{\text{Number of People / 1000 sf}}{1000}}{2} \qquad 15\ \text{CFM}$$

The concept of transfer and/or recirculated air is very important, because it allows a single space-conditioning system to serve areas requiring different fractions of outdoor air in their supplies. Rather than establishing the outdoor ventilation rate on the basis of the zone requiring the *highest* outdoor air fraction, this exception allows the ventilation rate to be based on the *average* required by all spaces served by the system.

Required ventilation rates for a two-space building are illustrated in Example 4-8. When each space is served by a separate constant volume system, the calculation and application of ventilation rate is straightforward, and each space will always receive its design outdoor air quantity. However, a central system serving both spaces does not deliver the design outdoor air quantity to each space. Instead, one space receives more than its allotted share, and the other less. This is because the training room has a higher design outdoor ventilation rate and/or a lower cooling load relative to the other space. The *Standards* permit this, provided the system meets the requirements described in items 2a, 2b and 2c above.

This mechanism of ventilation through transfer air is scientifically based and supported by ASHRAE Standard 62-1999. It works by transferring air with a low level of pollutants (from an over ventilated space) to a space with a higher level of pollutants. The less polluted transfer air is able to dilute the pollutants in the target space.

Example 4-8– Ventilation for a Two-room Building

Question

Consider a building with two spaces, each having an area of 1,000 square feet. One space is used for general administrative functions, and the other is used for classroom training. It is estimated that the office will contain seven people, and the classroom will contain 50 (fixed seating). What are the required outdoor ventilation rates?

Answer

1. For the office area, the design outdoor ventilation air is the larger of:

   7 people x 15 cfm/person = 105 cfm

   or

   1,000 ft^2 x 0.15 cfm/ft^2 = 150 cfm

   For this space, the design ventilation rate is 150 cfm.

2. For the classroom, the design outdoor ventilation air is the larger of:

   50 people x 15 cfm/person = 750 cfm

   or

   1,000 ft^2 x 0.15 cfm/ft^2 = 150 cfm

   For this space the design ventilation rate is 750 cfm.

Assume the total supply air necessary to satisfy cooling loads is 1000 cfm for the office and 1,500 cfm for the classroom. If each space is served by a separate system, then the required outdoor ventilation rate of each system is 150 cfm and 750 cfm, respectively. This corresponds to a 15 percent outside air (OA) fraction in the office HVAC unit, and 50 percent in the classroom unit.

If both spaces are served by a central system, then the total supply will be (1,000 + 1,500) cfm = 2500 cfm. The required outdoor ventilation rate is (150 + 750) = 900 cfm total. The actual outdoor air ventilation rate for each space is:

Office OA = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm

Classroom OA = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While the actual OA cfm to the classroom is less than design (540 cfm vs. 750 cfm), the *Standards* allow this provided that the system always delivers at least 750 cfm to the classroom (including transfer or recirculated air), and that any transfer air is free of unusual contaminants.

The *Standards* specify the minimum outdoor ventilation rate to which the system must be designed. If desired, the designer may elect to take a more conservative approach. For example, the design outdoor ventilation rate may be determined using the procedures described in ASHRAE 62-1999, provided the resulting outdoor air quantities are no less than required by these *Standards*.

Direct Air Transfer

As described above, the *Standards* allow air to be directly transferred from other spaces as part of the “outdoor” supply to a space. The actual percentage of outdoor air present in the transfer air need not be taken into account as long as the total outdoor quantity required by all spaces is provided by the mechanical system. This method can be used for any space, but is particularly applicable to conference rooms and other rooms that have high ventilation requirements. Transfer air must be free from any unusual contaminants, and as such should not be taken directly from rooms where such sources of contaminants are anticipated.

Air may be transferred using any method that ensures a positive airflow. Examples include dedicated transfer fans, exhaust fans and fan-powered VAV boxes. A system having a ducted return may be balanced so that air naturally transfers into the space. Exhaust fans serving the space may discharge directly outdoors, or into a return plenum. Transfer systems should be designed to minimize recirculation of transfer air back into the space; duct work should be arranged to separate the transfer air intake and return points. When the location of conference rooms and other areas requiring high ventilation rates are known in advance, it is recommended that these spaces be provided with separate sources of outdoor air. Note also that other codes may restrict from where transfer air may be taken. For example, transfer air cannot be drawn from a fire-resistive corridor used for exit purposes. Transfer air can be transported through fire-rated partitions provided all code requirements, such as the use of fire and/or smoke dampers, are met.

Distribution of Outdoor Air to Zonal Units (§121(d))

When a zonal heating or cooling unit is located in a plenum and an outdoor supply is not directly connected to the unit, then the outdoor air must be ducted to discharge either:

1. Within five feet of the unit; or
2. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.

Water source heat pumps and fan coils are the most common application of this configuration. The unit fans should be controlled to run continuously during occupancy in order for the ventilation air to be circulated to the occupied space.

A central space-conditioning system(s) augmented by a few zonal units for spot conditioning may use transfer air from spaces served by the central system. A direct source of outdoor air is not required for each zonal unit. Similarly, transfer air may be used in buildings having central interior space-conditioning systems with outdoor air, and zonal units on the perimeter (without outdoor air).

While not required, the *Standards* recommend that sources of unusual contaminants be controlled through the use of containment systems that capture the contaminants and discharge them directly outdoors. Such systems may include exhaust hoods, fume hoods, small space exhausts and differential pressure control between spaces. The designer is advised to consult ASHRAE handbooks or other publications for guidance in this subject.

H. Ventilation System Operation and Controls (§121(c) & §121(f))

Outdoor Ventilation Air and VAV Systems

Except for systems employing *Energy Commission* certified demand control ventilation devices, the *Standards* require that the minimum rate of outdoor air calculated per §121(b)2 be provided to each space *at all times* when the space is usually occupied (§121(c)1). For spaces served by VAV systems, this implies that the minimum supply setting of each VAV box should be no less than the design outdoor ventilation rate calculated for the space, unless transfer air is used. If transfer air is used, the minimum box position, plus the transfer air, should meet the minimum ventilation rate. If transfer air is not used, the box should be controlled so that the minimum required airflow is maintained at all times.

The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity (§121(c)1). Therefore, a means of continuously providing at least the minimum amount of outdoor air should be incorporated into the design of the system. Such means may include:

1. Separate outdoor air fans with modulating controls that introduce a fixed amount of air into the return or mixed air sections of the system; or
2. Controls that maintain a fixed differential between supply and return fan air flow rates. The differential may be measured with air flow stations, or determined during commissioning via an air balance, taking multiple measurements of flow at different fan capacities; or

Example 4-9– Minimum VAV CFM

Question

If the minimum required ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for its VAV box when the designed percentage of outdoor air in the supply is 20 percent?

Answer

The minimum allowed airflow may be as low as 150 cfm provided that enough outdoor air is supplied to all spaces combined to meet the requirements of §121(b)2 for each space individually.

3. Exhaust fans, including toilet exhausts, that exhaust a fixed amount of air from the building during all occupied hours; or

4. Outside air dampers having minimum settings that vary with fan capacity. This will necessitate an air balance taking multiple measurements of outdoor air flow in comparison to fan capacity so that a curve can be developed. A controller capable of being programmed with the curve will be critical, as is some means of measuring fan capacity. Capacity can be measured by an air flow station, or correlated to an inlet vane signal, a variable frequency drive (VFD) signal, or fan motor amps; or

5. Balancing the space-conditioning system to provide the required outdoor ventilation at the minimum expected supply airflow.

If the space-conditioning system incorporates an air economizer, the balance may be made at the expected supply airflow corresponding to the conditions at which the economizer closes to minimum. For example, assume the economizer closes to minimum at an outdoor temperature of 70°F. Below this temperature, the economizer will usually be delivering more than the minimum outdoor ventilation rate in order to satisfy space cooling loads. Therefore, the operating point of concern for the minimum outdoor damper setting corresponds to the supply airflow normally expected at 70°F.

For systems that do not have a return fan, the actual outdoor ventilation rate will increase as the fan supply increases and the static pressure on the suction side of the fan drops. In this case, the load calculations and equipment sizes as documented on the compliance forms must be based on the outdoor ventilation rate expected at design conditions, and not the minimum as calculated in this section.

Since this approach can force equipment to be larger than otherwise required and may also waste energy, other solutions are preferred; or

6. Provide dedicated intake and supply fans designed to meet minimum ventilation requirements; or

Other methods approved by the enforcement agency.

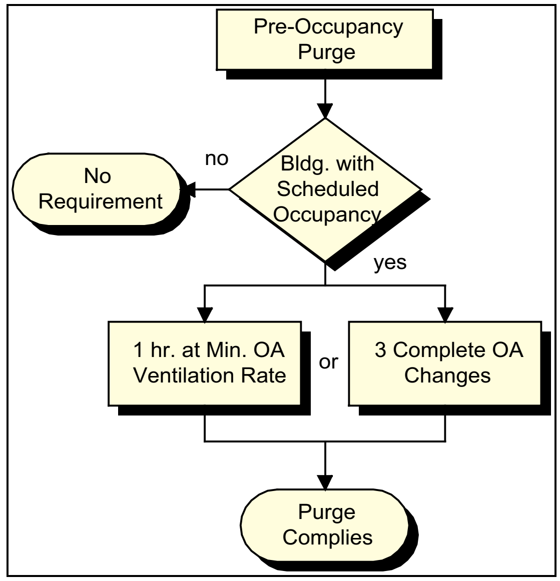
Pre-Occupancy

Since many indoor air pollutants are out gassed from the building materials and furnishings, the *Standards* require that buildings having a scheduled operation be purged before occupancy (§121(c)2). In the hour immediately prior to occupancy, outdoor ventilation must be provided at a rate equal to the lesser of:

1. The minimum required ventilation rate; or
2. Three complete air changes per hour.

The first criteria will normally apply to office spaces when the outdoor damper is in the minimum ventilation position. The second criteria would apply to spaces having higher ventilation rates, or to offices if the purge is accomplished by using an economizer with dampers fully open. *Three complete air changes* means an amount of ventilation air equal to three times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be less than an hour.

Figure 4-9– Pre-Occupancy Purge Flowchart



A pre-occupancy purge is not required for buildings or spaces that are not occupied on a scheduled basis, such as storage rooms. Also, a purge is not required for spaces provided with natural ventilation.

Example 4-10– Purge Period

Question

What is the length of time required to purge a space 10 feet high with an outdoor ventilation rate of 1.5 cfm/ft² ?

Answer

For 3 air changes, each square foot of space must be provided with:

OA volume = 3 x 10 = 30 cubic feet

At a rate of 1.5 cfm/ft² , the time required is:

Time = 30 cf / 1.5 cfm/ft² = 20 minutes

Example 4-11– Purge with Natural Ventilation

Question

In a building with natural ventilation, do the windows need to be left open all night to accomplish a building purge?

Answer

No. A building purge is required only for buildings with mechanical ventilation systems.

Example 4-12– Purge with Occupancy Timer

Question

How is a purge accomplished in a building without a regularly scheduled occupancy whose system operation is controlled by an occupancy sensor?

Answer

There is no purge requirement for this building. Note that occupancy sensors and manual timers can only be used for system control in buildings that are intermittently occupied.

Note: Most systems employ controls to warm-up or cool-down the building prior to occupancy. These "warm-up", "pull down" or "optimum start" cycles are often run with the outside air dampers fully closed to save energy, to speed the period of warm up (or pull down), and to reduce the installed equipment capacity. To meet the pre-occupancy purge requirements with these controls, the system schedule should be started 1 hour prior to the anticipated occupancy. This permits the warm-up or pull-down cycle to complete prior to the commencement of the purge.

Demand Control Ventilation (§121(c)1, 2 & 4)

Demand controlled ventilation systems reduce the amount of system outdoor or space supply air in response to a measured level of trace pollutants in either the zone or return airstream. These devices are typically controlled with a carbon dioxide (CO_2) sensor. The Standard requires their use on systems which *primarily serve areas with fixed seating and occupant densities less than or equal to 10 square foot per person, or identified in Chapter 10 of the UBC as either "Assembly Areas, Concentrated Use (without fixed seats)" or "Auction Rooms"* (§121(c)3) and that have a design outdoor air rate equal to or exceeding 3,000 cfm. The Standard also permits their use on any intermittently occupied spaces.

Demand controlled ventilation systems work by directly controlling the amount of dilution air in response to a measured pollutant. They save energy if the rate of pollutant generation varies over time. In densely occupied portions of commercial buildings, the primary pollutants that drive the ventilation rates are related to the occupants (primarily cosmetics, biological contaminants and odor). The occupant density in turn can be measured in proxy through CO_2. These systems can work both at the zone level (by varying the supply and/or transfer air) or at the system level (by varying the outdoor air). They are most applicable to densely occupied spaces like auditoriums, conference rooms, lounges or areas with smoking. Where permitted or required by the Standard, demand controlled ventilation systems cannot reduce the ventilation supplies below a floor of 0.15 cfm/ft^2 during normally occupied times. This floor is provided to ventilate the building based pollutants (e.g. paint, carpet, fabrics, etc.).

Example 4-13– Demand Controlled Ventilation

Question

Does an air-handling unit serving a 2,000 *ft²* auditorium with fixed seating for 240 people require demand controlled ventilation?

Answer

Yes. There are two tests for the requirement.

The first test is the occupant density. This space has 2,000 *ft²* /240 people or 8.3 *ft²* /person.

The second test is the outdoor air requirement at design. With 240 people at 15 cfm/person (§121(b)2B), this space requires 3,600 cfm of ventilation air. Demand control ventilation is required for spaces with occupant densities less than or equal to 10 *ft²* /person where the design outdoor air capacity is greater than or equal to 3,000 cfm (§121(c)3).

A single CO_2 sensor could be used for this space provided it is certified by the Commission and is certified by the manufacturer to cover 2,000 ft² of space. The sensor could be placed either directly in the space or in the return air stream (§121(c)4).

Example 4-14– Demand Controlled Ventilation

Question

If two equally sized units are used on the auditorium in the Example 4-13- are demand ventilation controls required?

Answer

No. Although the space still has an occupant density less than 10 ft² /person, each HVAC unit has less than 3,000 cfm of ventilation air (if they are equally sized, they will have 1,800 cfm each). Even though demand ventilation controls are not required for these units, they are permitted and should be considered for the application.

Fan Cycling

While §121(c)1 requires that ventilation be continuous during normally occupied hours, Exception No. 2 allows the ventilation to be disrupted for not more than five minutes out of every hour. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

This restriction limits the duty cycling of fans by energy management systems to not more than five minutes out of every sixty. In addition, when a space-conditioning system that also provides ventilation is controlled by a thermostat incorporating a fan “On/Auto” switch, the switch should be set to the “On” position. Otherwise, during mild conditions, the fan may be off the majority of the time.

Variable Air Volume (VAV) Changeover Systems

Some VAV systems provide conditioned supply air, either heated or cooled, through a single set of ducting. These systems are commonly referred to as "single duct VAV systems." In the event that heating is needed at the same time that cooling is needed in one or more different spaces, the system must alternate between supplying heated and cooled air. When the supply air is heated, for example, the spaces requiring cooling are isolated (cut off) by the VAV dampers and must wait until the system switches back to cooling mode.

Systems of this type may not meet the ventilation requirements if improperly applied. Changeover systems that are applied to a common building orientation (e.g. east) are unlikely to have zones simultaneously requiring heating while others require cooling. Where changeover systems span multiple orientations the designer must make control provisions to ensure that no zone is shut off for more than 5 minutes per hour.

Adjustment of Ventilation Rate

§121(b) specifies the minimum required outdoor ventilation rate, but does not restrict the maximum. However, if the designer elects to have the space-conditioning system operate at a ventilation rate higher than the rate required by the *Standards*, then the *Standards* require that the space-conditioning system must be adjustable so that in the future the ventilation rate can be reduced to the amount required by the *Standards* or the rate required for make-up of exhaust systems that are required for a process, for control of odors, or for the removal of contaminants within the space §121(e)).

In other words, a system can be designed to supply higher than minimum outside air volumes provided dampers or fan speed can be adjusted to allow no more than the minimum volume if, at a later time, someone decides it is desirable. The *Standards* preclude a system designed for 100 percent outdoor air, with no provision for any return air, unless the supply air quantity can be adjusted to be equal to the design minimum outdoor air volume. The intent is to prevent systems from being designed that will permanently over ventilate spaces.

Miscellaneous Dampers (§122(f))

Dampers should not be installed on combustion air intakes, or where prohibited by other provisions of law (§122(f) Exception No. 3 & 4). If the designer elects to install dampers on shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in accordance with applicable fire codes.

Completion and Balancing (§121(f))

Before an occupancy permit is granted for a new building or space, or before a new space-conditioning or ventilating system serving a building or space is operated for normal use, the mechanical ventilation system serving the building or space must be documented in accordance with Title 8, Section 5142(b) of the California Safety Code (1987) to be providing no less than the ventilation rate required by the *Standards* as determined using one of the following procedures:

1. Balancing: The system shall be balanced in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983), or Associated Air Balance Council (AABC) National Standards (1989); or
2. Outside Air Certification: The system shall provide the minimum outside air as shown on the mechanical drawings, and shall be measured by the installing licensed C-20 mechanical contractor and certified by either the design mechanical engineer, the installing licensed C-20 mechanical contractor, or the person with overall responsibility for the design of the ventilation system; or
3. Outside Air Measurement: The system shall be equipped with a calibrated local or remote device capable of measuring the quantity of outside air on a continuous basis and displaying that quantity on a readily accessible display device; or
4. Another method approved by the *Energy Commission*.

Note: *Additional code requirements may also apply in some areas of California, such as for the City of Los Angeles. This certification is regarded as "documentation in writing" and becomes the "first record" required by Title 8 of the new building.*

Example 4-15– Maintenance of Ventilation System

Question

In addition to these commissioning requirements for the ventilation system, are there any periodic requirements for inspection?

Answer

These Standards do not contain any such requirements. However, Section 5142 of the General Industry Safety Orders, Title 8, California Safety Code (1987): Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation, states the following:

(b) Operation and Maintenance

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC systems shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division (as defined in Section 3207 of Title 8), to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this section.

I. Required Controls for Space Conditioning Systems (§122)

This section covers controls that are mandatory for all system types, including:

1. Zoning and thermostatic control,
2. Shut-off and temperature setup/setback of space-conditioning systems, and
3. Off-hours space isolation.

Zone Thermostatic Control (§122(a), (b) and (c))

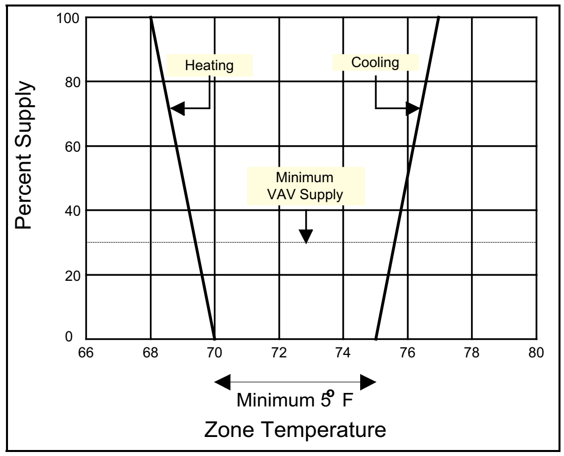
A thermostat must be provided for each *space-conditioning zone* or dwelling unit to control the supply of heating and cooling energy within that zone (§122(a)). The thermostat must have the following characteristics:

1. When used to control **heating**, the thermostat must be adjustable down to 55°F or lower.

2. When used to control **cooling**, the thermostat must be adjustable up to 85°F or higher.

When used to control both **heating and cooling**, the thermostat must be adjustable from 55°F to 85°F and also provide a temperature range or **dead band** of at least 5°F. When the space temperature is within the dead band, heating and cooling energy must be shut off or reduced to a minimum. A dead band is not required if the thermostat requires a manual changeover between the heating and cooling modes §122(b) Exception No. 1).

Figure 4-10– Proportional Control Zone Thermostat



The setpoint may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Example 4-16– Direct Digital Control of Space Temperature

Question

Can an energy management system be used to control the space temperatures?

Answer

Yes, provided the space temperature setpoints can be adjusted, either locally or remotely. Some DDC systems employ a single cooling setpoint and a fixed or adjustable dead band. These systems comply if the dead band is adjustable or fixed at 5°F or greater.

Thermostats with adjustable setpoints and dead band capability are not required for zones that must have constant temperatures to prevent the degradation of materials, a process, or plants or animals §122(b) (Exception No. 2). Included in this category are computer rooms, clean rooms, hospital patient rooms, museums, etc.

Hotel/Motel Guest Rooms and High-Rise Residential Dwellings Thermostats

The *Standards* require that thermostats in hotel and motel guest rooms have:

1. **Numeric temperature setpoints** in °F, and

2. **Setpoint stops** that prevent the thermostat from being adjusted outside the normal comfort range. These stops must be concealed so that they are accessible only to authorized personnel.

The *Standards* effectively prohibit thermostats having 'warmer/cooler' or other labels with no temperature markings in this type of occupancy (§122(c)).

The *Standards* require (§122(c)) that thermostats in High-rise residential dwelling units must have setback capabilities and meet all the requirements in §150(i).

Perimeter Systems Thermostats

Supplemental perimeter heating or cooling systems are sometimes used to augment a space-conditioning system serving both interior and perimeter zones. §122(a) Exception allows this, provided controls are incorporated to prevent the two systems from conflicting with each other. In this case, the *Standards* require that:

1. The perimeter system must be designed solely to offset envelope heat losses or gains; and

2. The perimeter system must have at least one thermostatic control for each building orientation of 50 feet or more; and

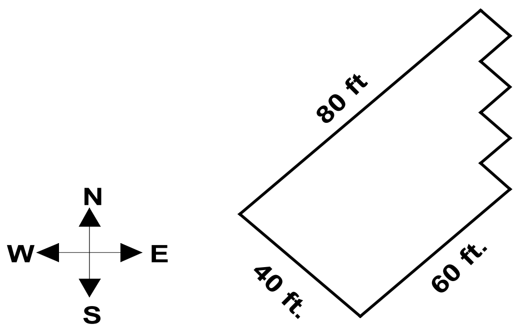
3. The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

The intent is that all major exposures be controlled by their own thermostat, and that the thermostat be located within the conditioned perimeter zone. Other temperature controls, such as outdoor temperature reset or solar compensated outdoor reset, do not meet the requirements of the *Standards*.

Example 4-17– Perimeter Systems Thermostats

Question

What is the perimeter zoning required for the building shown here?



Answer

The southeast and northwest exposures must each have at least one perimeter system control zone, since they are more than 50 feet in length. The southwest exposure and the serrated east exposure do not face one direction for more than 50 continuous feet in length. They are therefore “minor” exposures and need not be served by separate perimeter system zones, but may be served from either of the adjacent zones.

Shut-off and Temperature Setup/Setback (§122(e))

For specific occupancies and conditions, each space-conditioning system must be provided with controls that can automatically shut off the equipment during unoccupied hours. The control device can be either:

1. An *automatic time switch* device must have the same characteristics that lighting devices must have, as described in Section 5.1.1C. This can be accomplished with a seven day programmable thermostat with a battery backup of at least ten hours.

A manual override accessible to the occupants must be included in the control system design either as a part of the control device, or as a separate override control. This override shall allow the system to operate up to four hours during normally unoccupied periods.

2. An *occupancy sensor*. Since a building ventilation purge is required prior to normal occupancy (§121(c)2), an occupancy sensor may be used to control the availability of heating and cooling, but should not be used to control the outdoor ventilation system (unless the building is intermittently occupied). In such a case, an automatic time switch should be used instead.

When an automatic time switch is used to control ventilation while occupancy sensors are used simultaneously to control heating and cooling, the controls should be interlocked so that ventilation can be provided during off-hours operation.

3. A *four-hour timer* that can be manually operated to start the system. As with occupancy sensors, the same restrictions apply to controlling outdoor air ventilation systems.

When shut down, the controls shall automatically restart the system to maintain:

1. A **setback heating thermostat setpoint**, if the system provides mechanical heating. Thermostat setback controls are not required in areas where the Winter Median of Extremes outdoor air temperature is greater than 32°F (§122(e)2.A and Exception).

2. A **setup cooling thermostat setpoint**, if the system provides mechanical cooling. Thermostat setup controls are not required in areas where the Summer Design Dry Bulb 0.5 percent temperature is less than 100°F §122(e)2.B and Exception).

Example 4-18–Office Occupancy Sensor

Question

Can occupancy sensors be used in an office to shut off the VAV boxes during periods the spaces are unoccupied?

Answer

Not completely. The occupancy sensor could be used to reduce the VAV box airflow to the minimum allowed for ventilation. It should not shut the airflow off completely, because §121(c) requires that ventilation be supplied to each space at all times when the space is usually occupied.

Example 4-19–Automatic Time Switches with Multiple Systems

Question

Must a 48,000 square foot building with 35 fan coil units have 35 time switches?

Answer

No. More than one space-conditioning system may be grouped on a single time switch, subject to the area limitations required by the isolation requirements (see Isolation). In this case, the building would need two isolation zones, each no larger than 25,000 square feet, and each having its own time switch.

Example 4-20–Thermostat with Sensors

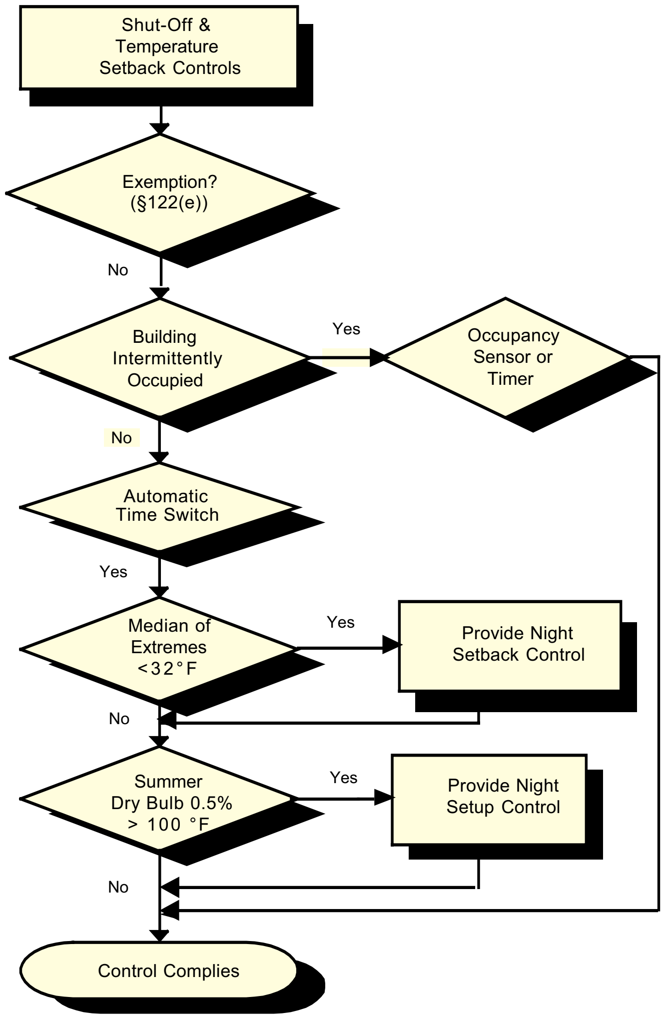
Question

Can a thermostat with setpoints determined by sensors (such as a bi-metal sensor encased in a bulb) be used to accomplish a night setback?

Answer

Yes. The thermostat must have two heating sensors, one each for the occupied and unoccupied temperatures. The controls must allow the setback sensor to override the system shutdown

Figure 4-11– Shut-Off and Setback Controls Flowchart



These provisions are required by the *Standards* to reduce the likelihood that shut-off controls will be circumvented to cause equipment to operate continuously during unoccupied hours.

Automatic shut-off, setback and setup devices are not required where:

1. It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously (§122(e) Exception No. 1); or
2. It can be demonstrated to the satisfaction of the enforcement agency that shutdown, setback, and setup will not result in a decrease in overall building source energy use (§122(e) Exception No. 2); or
3. *Systems* have a full load demand less than 2 kW, or 6,828 Btu/hr, if they have a readily accessible manual shut-off switch (§122(e) Exception No. 3). Included is the energy consumed within all associated space-conditioning systems including compressors, as well as the energy consumed by any boilers or chillers that are part of the system.

4. Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch §122(e) Exception No.4).
5. The mechanical system serves retail stores and associated malls, restaurants, grocery stores, churches, or theaters equipped with a 7-day programmable timer.

Example 4-21– Time Control for Fan Coils

Question

If a building has a system comprised of 30 fan coil units, each with a 300 watt fan, a 500,000 Btu/hr boiler, and a 30-ton chiller, can an automatic time switch be used to control only the boiler and chiller (fan coils operate continuously)?

Answer

No. The 2 kW criteria applies to the system as a whole, and is not applied to each component independently. While each fan coil only draws 300 watts, they are served by a boiler and chiller that draw much more. The consumption for the system is well in excess of 2 kW.

Assuming the units serve a total area of less than 25,000 square feet (see Isolation), one time switch may control the entire system.

Dampers (§122(f))

Outdoor air supply and exhaust equipment must incorporate dampers that automatically close when fans shut down. The dampers may either be motorized, or of the gravity type.

Damper control is not required where it can be demonstrated to the satisfaction of the enforcement agency that the space-conditioning

system must operate continuously (Exception No. 1). Nor is damper control required on gravity ventilators or other non-electrical equipment, provided that readily accessible manual controls are incorporated (Exception No. 2).

Damper control is also not required at combustion air intakes and shaft vents, or where prohibited by other provisions of law (Exceptions No. 3 and 4). If the designer elects to install dampers or shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in a fire in accordance with applicable fire codes.

Isolation Area Devices (§122(g))

Large space-conditioning systems serving multiple zones may waste considerable quantities of energy by conditioning all zones when only a few zones are occupied. Typically, this occurs during evenings or weekends when only a few people are working. When the total area served by a system exceeds 25,000 square feet, the *Standards* require that the system be designed, installed and controlled with area isolation devices to minimize energy consumption during these times. The requirements are:

1. The building shall be divided into isolation areas, the area of each not exceeding 25,000 square feet. An isolation area may consist of one or more *zones*.
2. Each isolation area shall be provided with isolations devices such as valves or dampers, that allow the supply of heating or cooling to be setback or shut off independently of other isolation areas.
3. Each isolation area shall be controlled with an automatic time switch, occupancy sensor, or manual timer. The requirements for these shut-off devices are the same as described previously in §122(e)1. As discussed previously for occupancy sensors, a building purge must be incorporated into the control sequences for normally occupied spaces, so occupancy sensors and manual timers are best limited to use in those areas that are intermittently occupied.

Any zones requiring continuous operation do not have to be included in an isolation area.

Example 4-22– Isolation Zones

Question

How many isolation zones does a 55,000 *ft²* building require?

Answer

At least three. Each isolation zone may not exceed 25,000 square feet.

Isolation of Zonal Systems

Small zonal type systems such as water loop heat pumps or fan coils may be grouped on automatic time switch devices, with control interlocks that start the central plant equipment whenever any isolation area is occupied. The isolation requirements apply to equipment supplying heating and cooling only; central ventilation systems serving zonal type systems do not require these devices.

Isolation of Central Air Systems

Figure 4-12 below depicts four methods of zone isolation with a central variable air volume system:

1. On the lowest floor programmable DDC boxes can be switched on a separate time schedule for each zone or blocks of zones. When off the boxes can be programmed to go to zero airflow. Note this form of isolation can be used for sections of a single floor distribution system.

2. On the second floor, normally closed pneumatic or electric VAV boxes are used to isolate zones or groups of zones. In this scheme the control source (pneumatic air or control power) for each group is switched on a separate control signal from an individual time schedule. Again this form of isolation can be used for sections of a single floor distribution system.

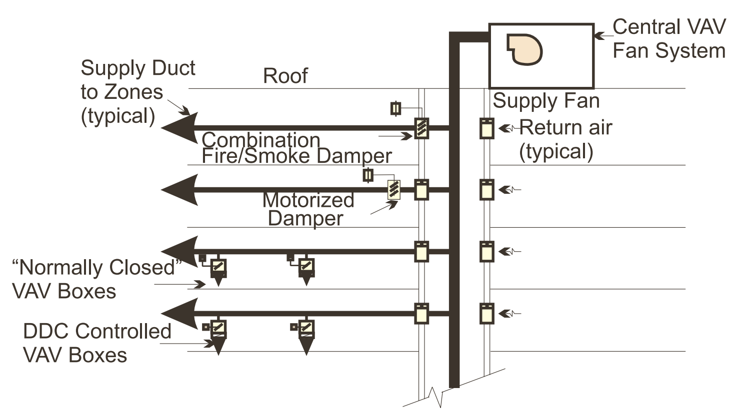
3. On the third floor isolation is achieved by inserting a single motorized damper on the trunk of the distribution ductwork. With the code requirement for fire/smoke dampers (see next bullet) this method is somewhat obsolete. When applied this method can only control a single trunk duct as a whole. Care must be taken to integrate the motorized damper controls into the fire/life safety system.

4. On the top floor a combination fire smoke damper is controlled to provide the isolation. Again this control can only be used on a single trunk duct as a whole. Fire/smoke dampers required by code can be used for isolation at virtually no cost provided that they are wired so that the fire life-safety controls take precedence over off-hour controls. (Local fire officials generally allow this dual usage of smoke dampers since it increases the likelihood that the dampers will be in good working order in the event of a fire.)

Note that no isolation devices are required on the return.

In addition to the isolation of supply, isolation should be provided on exhaust fans that serve the isolation zones.

Figure 4-12– Isolation Methods for a Central VAV System



Example 4-23– Isolation Zone Purge

Question

Does each isolation zone require a ventilation purge?

Answer

Yes.

Isolation of Central Plants

The *Standards* do not require any isolation of central plant equipment. It is recommended that the number and type of boilers, chillers, pumps, and other central equipment be chosen so that the plant efficiency at part load is equal to or greater than the efficiency at full load. Since space-conditioning systems seldom operate at peak conditions, this approach will reduce energy consumption during times of normal occupancy, in addition to off-hours.

J. Requirements for Pipe Insulation (§123)

1. Most piping conveying either mechanically heated or chilled fluids for space conditioning or service water heating must be insulated in accordance with §123. The required thickness of piping insulation depends on the temperature of the fluid passing through the pipe, the pipe diameter, the function of the pipe within the system, and the insulation's thermal conductivity.

Table 4-3 (Table No. 1-G in the *Standards*) specifies the requirements in terms of inches of fiberglass or foam pipe insulation. In this table, runouts are defined as being less than two-inches in diameter, less than 12 feet long, and connected to fixtures or individual terminal units.

Piping that does not require insulation includes the following:

1. Factory installed piping within certified space-conditioning equipment.
2. Piping that conveys fluid with a design operating temperature range between 60°F and 105°F, such as cooling tower piping or piping in water loop heat pump systems.
3. Piping that serves process loads, gas piping, cold domestic water piping, condensate drains, roof drains, vents or waste piping.

Note: Designers may specify exempt piping conveying cold fluids to be insulated in order to control condensation on the surface of the pipe. Examples may include cold domestic water piping, condensate drains and roof drains. In these cases, the insulation R-value is specified by the designer and is not subject to these regulations.

4. Where the heat gain or heat loss, to or from piping without insulation, will not increase building source energy use. For example, piping connecting fin-tube radiators within the same space would be exempt.

   This exception would not exempt piping in solar systems. Solar systems typically have backup devices that will operate more frequently if piping losses are not minimized.

Conductivities and thicknesses listed in Table 4-3 are typical for fiberglass and foam. When insulating materials are used that have conductivities different from those listed here for the applicable fluid range, such as calcium silicate, Equation 4-1 must be used to calculate the required insulation thickness.

When a pipe carries cold fluids, condensation of water vapor within the insulation material may impair the effectiveness of the insulation, particularly for applications in very humid environments or for fluid temperatures below 40°F. Examples include refrigerant suction piping and low-temperature thermal energy storage (TES) systems. In these cases, manufacturers should be consulted and consideration given to low permeability vapor barriers, or closed-cell foams.

The Standard also requires that exposed pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

2. Insulation exposed to weather shall be suitable for outdoor service; e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

3. Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall include a vapor retardant located outside the insulation (unless the insulation is inherently vapor retardant), all penetrations and joints of which shall be sealed.

Table 4-3 - Pipe Insulation Thickness

Fluid Temperature Range	Conductivity Range (in Btu-inch per hour per sf. per degree F)	Insulation Mean Rating Temperature	Nominal Pipe Diameter (in inches)					
			Runouts up to 2	1 and Less	1.25 - 2	2.50 - 4	5 - 6	8 and Larger
			Insulation Thickness Required (in inches)					
Space Heating Systems (Steam, Steam Condensate and Hot Water)								
Above 350	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
Service Water Heating Systems (recirculating sections, all piping in electric trace tape systems, and the first 8 feet of piping from the storage tank for non-recirculating systems)								
Above 105	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
Space Cooling Systems (Chilled Water, Refrigerant, and Brine)								
40-60	0.23-0.27	75	0.5	0.5	0.5	1.0	1.0	1.0
Below 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

Equation 4-8– Insulation Thickness

$$T = PR[(1 + t/PR)^{K/k} – 1]$$

Where:

T = Minimum insulation thickness for material with conductivity K, inches.

PR = Pipe actual outside radius, inches.

t = Insulation thickness from Table 4-3, inches.

K = Conductivity of alternate material at the mean rating temperature indicated in Table 4-3 for the applicable fluid temperature range, in Btu-in/(hr-ft² -°F).

k = The lower value of the conductivity range listed in Table 4-3 for the applicable fluid temperature, Btu-in/(hr-ft² -°F).

Example 4-24– Pipe Insulation Thickness

Question

What is the required thickness for calcium silicate insulation on a 4 inch diameter pipe carrying a 300°F fluid?

Answer

From Table 4-3, the required insulation thickness is 2.5 inches for a 4 inch pipe in the range of 251-350°F. The mean conductivity at this temperature is listed as 0.29 (Btu-in) / (hr-ft² -°F). From manufacturer’s data, it is determined that the conductivity of calcium silicate at 300°F is 0.45 Btu-in/(hr-ft² -°F). The required thickness is therefore:

$$T = PR[(1 + t/PR)K/k - 1]$$

$$T = 4"[(1 + 2.5/4)0.45/0.29 - 1]$$

$$T = 4.3 \text{ inches}$$

When insulation is not available in the exact thickness calculated, the installed thickness should be the next larger available size.

K. Requirements for Air Distribution System Ducts and Plenums (§124)

Poorly sealed or poorly insulated duct work can cause substantial losses of air volume and energy. The 2001 amendments include more detailed requirements for constructing ducts and plenums. All air distribution system ducts and plenums, including building cavities, mechanical closets, air handler boxes and support platforms used as ducts or plenums, are required to be installed, sealed, and insulated in accordance with the 1998 California Mechanical Code (CMC) Sections 601, 603, 604 and Standard 6-3. On or after the effective date designated by the California Building Standards Commission for the 2000 CMC, duct installation, sealing and insulation shall comply with Sections 601, 602, 604, 605 and Standard 6-5 of the 2000 CMC.

Installation and Insulation (§124(a))

Ducts or plenums conveying conditioned air must either be insulated to R-4.2 or any higher level required by
space (on or after the effective date designated by the California Building Standards Commission for the 2000 CMC, duct insulation shall comply with Section 605 of the 2000 CMC). CMC insulation requirements are reproduced in Table 4.4. The following are also required:

Mechanically fasten connections between metal ducts and the inner core of flexible ducts.

Seal openings with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A or UL 181B.

When mastic or tape is used to seal openings greater than 1/4 inch, a combination of mastic and mesh or mastic and tape must be used.

Duct and Plenum Materials (§124(b))

Factory-Fabricated Duct Systems (§124(b)1)

Factory-fabricated duct systems must meet the following requirements:

Duct and closure systems comply with UL 181, including collars, connections and splices, and must be UL labeled.

Pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts comply with UL 181.

Pressure-sensitive tapes and mastics used with flexible ducts comply with UL 181 or UL 181B.

Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Field-Fabricated Duct Systems (§124(b)2)

Field-fabricated duct systems must meet the following requirements:

1998 CMC Section 604 or be enclosed entirely in conditioned

Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems comply with UL 181. Pressure-sensitive tapes, mastics, aerosol sealants or other closure systems must meet applicable requirements of UL 181, UL 181A or UL 181B.

Mastic Sealants and Mesh.

Sealants comply with UL 181, UL 181A, or UL 181B, and must be non-toxic and water resistant.

Sealants for interior applications pass ASTM tests C 731(extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.

Sealants for exterior applications shall pass ASTM tests C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.

Sealants and meshes shall be rated for exterior use.

Pressure-sensitive tapes comply with UL 181, UL 181A or UL 181B.

Drawbands used with flexible duct shall:

Be either stainless-steel worm-drive hose clamps or uv-resistant nylon duct ties.

Have a minimum tensile strength rating of 150 pounds.

Be tightened as recommended by the manufacturer with an adjustable tensioning tool.

Aerosol-Sealant Closures.

Aerosol sealants meet applicable requirements of UL 181, 181A or 181B and must be applied according to manufacturer specifications.

Tapes or mastics used in combination with aerosol sealing must meet the requirements of this section.

Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Duct Insulation R-Values (§124(c), 124(d) & 124(e))

The 2001 amendments include requirements for the labeling, measurement and rating of duct insulation. These include the following:

Insulation R-Values shall be based on the insulation only and not include air-films or the R-Values of other components of the duct system.

Insulation R-Values shall be tested *C-values at 75°F mean temperature at the installed thickness, in accordance with ASTM C 518-85 or ASTM C 177-85.*

The installed thickness of duct insulation for purpose of compliance shall be the nominal thickness for duct board, duct liner, factory made flexible air ducts and factory-made rigid ducts.

The installed thickness of duct insulation for purpose of compliance shall be 75% of its nominal thickness for duct wrap.

Insulated flexible air ducts must bear labels no further than 3 feet apart that state the installed R-Value (as determined per the requirements of the Standard).

A typical duct wrap, nominal 1-1/2" and 0.75 pcf will have an installed rating of R-4.2 with 25% compression.

Table 4-4 - Duct Insulation Requirements

DUCT LOCATION [1]	INSULATION R-VALUE MECHANICALLY COOLED	HEATING ZONE	INSULATION R-VALUE HEATING ONLY
On roof on exterior building	6.3	< 4,500 DD	2.1
		< 8,000 DD	4.2
Attics, garages, and crawl spaces	2.1	< 4,500 DD	2.1
		< 8,000 DD	4.2
In walls [2] and within floor to ceiling spaces[2]	2.1	< 4,500 DD	2.1
		< 8,000 DD	4.2
Within the conditioned space or in basements; return ducts in air plenums	None Required		None Required
Cement slab or within ground	None Required		None Required

[1] Vapor barriers shall be installed on supply ducts in spaces vented to the outside in geographic areas where the average July, August and September mean dew point temperature exceeds 60 degrees Fahrenheit.

[2] Insulation may be omitted on that portion of a duct which is located within a wall or a floor to ceiling space where:

a. Both sides of the space are exposed to conditioned air.
b. The space is not ventilated.
c. The space is not used as a return plenum.
d. The space is not exposed to unconditioned air.

Ceilings which form plenums need not be insulated.

NOTE: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

Source: Uniform Mechanical Code §604

Protection of Duct Insulation (§124(h))

The Standard requires that exposed duct insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

1. *Insulation exposed to weather shall be suitable for outdoor service; e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover.*
2. *Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.*

Example 4-25– Duct Sealing

Question

What are the sealing requirements in a VAV system having a static pressure setpoint of 1.25” w.g. and a plenum return?

Answer

All duct work located within the return plenum must be sealed in accordance with the CMC Sections 601,603, 604 (refer to §124). Pressure-sensitive tape, heat-seal tape and mastic may be used, if it meets the applicable requirement of UL 181, 181A, 181B, to seal joints and seams which are mechanically fastened per the CMC.

L. Service Water Systems (§113)

Efficiency and Controls (§113(a))

Any service water heating equipment must have integral automatic temperature controls that allow the temperature to be adjusted from the lowest to the highest allowed temperature settings for the intended use as listed in Table 3, Chapter 45 of the 1995 *ASHRAE Handbook, HVAC Applications Volume*.

Water heating systems in high-rise residential buildings must meet the energy budget requirements of the Residential Standards. Service water heaters installed in residential occupancies need not meet the temperature control requirement of §113 (a)1.

Multiple Temperature Usage (§113(b)1)

On systems that have a total capacity greater than 167,000 Btu/hr, outlets requiring higher than service water temperatures as listed in the 1995 *ASHRAE Handbook, HVAC Applications Volume* shall have separate remote heaters, heat exchangers, or boosters to supply the outlet with the higher temperature. This requires the primary water heating system to supply water at the lowest temperature required by any of the demands served for service water heating. All other demands requiring higher temperatures should be served by separate systems, or by boosters that raise the temperature of the primary supply.

Circulating Systems (§113(b)2)

Circulating service water systems must include a control capable of automatically turning off the circulating pump when hot water is not required. Such controls include automatic time switches, interlocks with HVAC time switches, occupancy sensors, and other controls that accomplish the intended purpose. Since residential occupancies have different supply requirements they do not have to meet the requirements of §113(b)2.

Public Lavatories (§113(b)3)

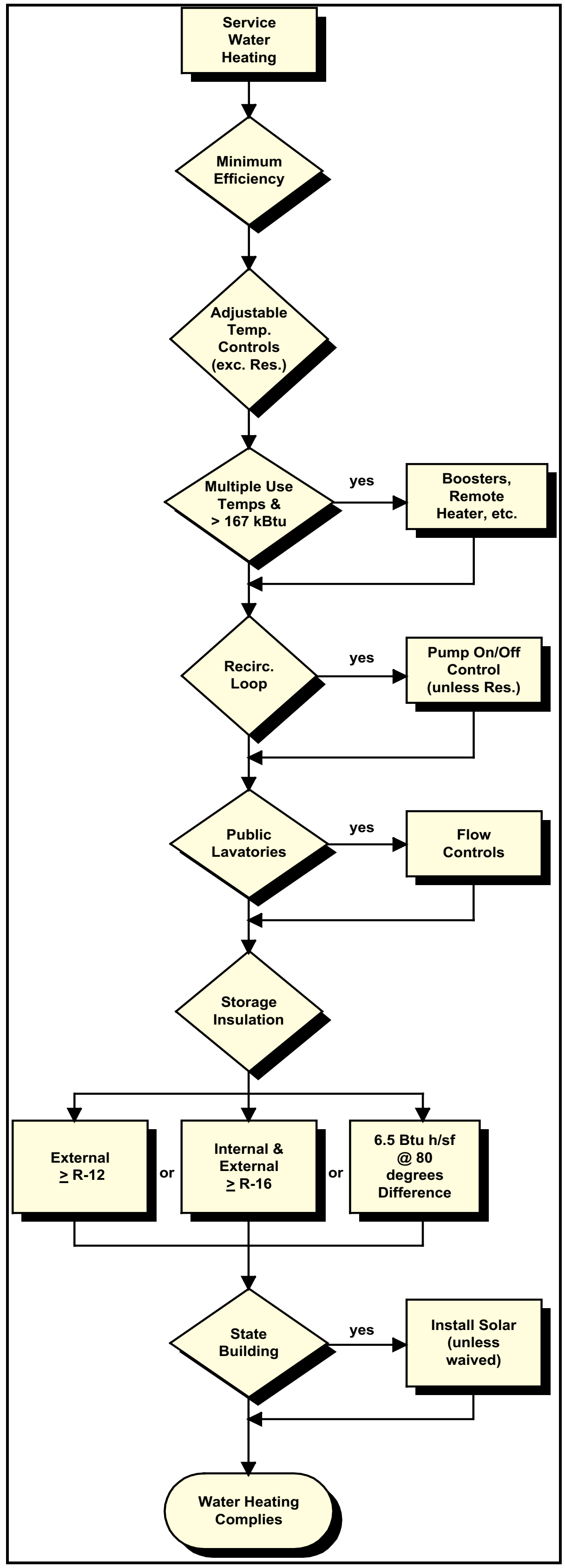
Lavatories in public restrooms must have controls that limit the water supply temperature to 110°F. Where a service water heater supplies only restrooms, the heater thermostat may be set to no greater than 110°F to satisfy this requirement; otherwise controls such as automatic mixing valves must be installed.

Storage Tank Insulation (§113(b)4)

Unfired water heater storage tanks and backup tanks for solar water heating systems must have:

1. **External insulation** with an installed R-value of at least R-12; or
2. **Internal and external insulation** with a combined R-value of at least R-16; or

Figure 4-13– Service Water Heating Flowchart



3. The **heat loss** of the tank based on an 80 degree F water-air temperature difference shall be less than 6.5 Btu per hour per square foot. This corresponds to an effective resistance of R-12.3.

Service Water Heaters in State Buildings (§113(b)5)

Any new building constructed by the State shall derive its service water heating from a system that provides at least 60 percent of the energy needed from site solar energy or recovered energy. This requirement may be waived for buildings where the State Architect determines that such systems are economically or physically infeasible.

M. Pool and Spa Heating Systems (§114)

Pool and spa heating systems must be certified by the manufacturer and listed by the *E*nergy Commission as having:

1. An **efficiency** of at least 78 percent when tested according to ANSI Standard Z21.56-1994; and
2. An **on-off switch** mounted on the outside of the heater in a readily accessible location that allows the heater to be shut-off without adjusting the thermostat setting; and
3. A permanent, easily readable, and weatherproof plate or card that gives **instructions** for the energy efficient operation of the pool or spa, and for the proper care of the pool or spa water when a cover is used; and
4. No **electric resistance heating**. The only exceptions are:
   a. *Packaged listed units* with fully insulated enclosures and tight fitting covers that are insulated to at least R-6. Package listed units are defined in the *National Electric Code* and are typically sold as self-contained, UL Listed spas; or

   b. Pools or spas deriving at least 60 percent of the annual heating energy from site solar energy or recovered energy.
5. **No pilot light.**

Pool and spa equipment must be installed with all of the following:

1. **Solar heater connection** - At least 36 inches of pipe between the filter and the heater must be provided to allow for the future addition of solar heating equipment.
2. A **cover** must be provided for outdoor pools and outdoor spas, unless at least 60 percent of the annual heating energy is provided by site solar energy or recovered energy.
3. **Directional inlets** must be provided for all pools that adequately mix the pool water.
4. A **time switch** must be provided for pools to control the operation of the circulation pump, to allow the pump to be set to run in the off-peak demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

   A time switch is not required where applicable public health standards require on-peak operation.

4.2.2 Prescriptive Approach

This section presents requirements that must be incorporated into the system design if the Prescriptive Path of compliance is used. Unlike Mandatory Requirements, however, these requirements may be traded off against other measures if the designer elects to use the Performance Path.

A. Sizing and Equipment Selection (§144(a))

The *Standards* require that mechanical heating and cooling equipment (including electric heaters and boilers) be the smallest size available, within the available options of the desired equipment line, that meets the design heating and cooling loads of the building or spaces being served. Depending on the equipment, oversizing can be either a penalty or benefit to energy usage. For vapor compression equipment, gross oversizing can drastically increase the energy usage and in some cases cause premature failure from short cycling of compressors. Boilers and water-heaters generally suffer lower efficiencies and higher standby losses if they are oversized. On the other hand, cooling towers, cooling coils, pumps and fans can actually improve in efficiency if oversized. Oversized distribution ductwork and piping can reduce system pressure losses and reduce fan and pump energy.

When equipment is offered in size increments, such that one size is too small and the next is too large, the larger size may be selected.

Packaged HVAC equipment may serve a space having substantially different heating and cooling loads. The unit size should be selected on the larger of the loads, based on either capacity or airflow. The capacity for the other load should be selected as required to meet the load, or if very small, should be the smallest capacity available in the selected unit. For example, packaged air-conditioning units with gas heat are usually sized on the basis of cooling loads. The furnace is sized on the basis of airflow, and is almost always larger than the design heating load.

Equipment may be oversized provided one or more of the following conditions are met:

1. It can be demonstrated to the satisfaction of the enforcing agency that oversizing will not increase building source energy use; or
2. Oversizing is the result of standby equipment that will operate only when the primary equipment is not operating. Controls must be provided that prevent the standby equipment from operating simultaneously with the primary equipment; or
3. Multiple units of the same equipment type are used, each having a capacity less than the design load, but in combination having a capacity greater than the design load. Controls must be provided to sequence or otherwise optimally control the operation of each unit based on load.

B. Load Calculations (§144(b))

For the purposes of sizing HVAC equipment, the designer shall use all of the following criteria for load calculations:

1. The heating and cooling system **design loads** must be calculated in accordance with the procedures described in the *ASHRAE Handbook, 1993, Fundamentals Volume*. Other load calculation methods, e.g. ACCA, SMACNA, *etc.* are acceptable provided that the method is ASHRAE-based. When submitting load calculations of this type, the designer must accompany the load calculations with a written affidavit certifying that the method used is ASHRAE-based. If the designer is unclear as to whether or not the calculation method is ASHRAE-based, the vendor or organization providing the calculation method should be contacted to verify that the method is derived from ASHRAE.

Example 4-26– Equipment Sizing

Question

Do the sizing requirements restrict the size of duct work, coils, filter banks, etc. in a built-up system?

Answer

The intent of the *Standards* is to limit the size of equipment which, if oversized, will consume more energy on an annual basis. Coils with larger face areas will usually have lower pressure drops than otherwise, and may also allow the chilled water temperature to be higher, both of which may result in a decrease in energy usage. Larger filter banks will also usually save energy. Larger duct work will have lower static pressure losses which may save energy, depending on the duct's location, length, and degree of insulation. An oversized airfoil fan with inlet vanes will not usually save energy, as the part load characteristics of this device are poor. The same fan with a variable frequency drive may save energy. Controls are also an important part of any system design.

The relationship between various energy consuming components may be complex, and is left to the designer's professional judgment. Note however, that when components are oversized, it must be demonstrated to the satisfaction of the enforcement agency that energy usage will not increase.

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2. **Indoor design conditions** of temperature and relative humidity for general comfort applications are not explicitly defined. Designers are allowed to use any temperature conditions within the "comfort envelope" defined by ANSI/ASHRAE 55-1992 or Chapter 8 of the *ASHRAE Handbook, 1993, Fundamentals Volume*. Winter humidification or summer dehumidification is not required.
3. **Outdoor design conditions** shall be selected from ASHRAE Publication SPCDX: Climatic Data for Region X, Arizona, California, Hawaii, and Nevada, 1982 for the following design conditions:

   Heating design temperatures shall be no lower than the temperature listed in the Winter Median of Extremes column.

   Cooling design dry bulb temperatures shall be no greater than the temperature listed in the Summer Design Dry Bulb 0.5% column. The design wet bulb temperature shall be no greater than the temperature listed in the Summer Design Wet Bulb 0.5% column.
4. **Outdoor Air Ventilation** loads must be calculated using the ventilation rates required in §121. At minimum, the ventilation rate will be 15 cfm/person or 0.15 cfm/ft², whichever is greater.
5. **Envelope** heating and cooling loads must be calculated using envelope characteristics including square footage, thermal conductance, solar heat gain coefficient and air leakage, consistent with the proposed design.
6. **Lighting** loads shall be based on actual design lighting levels or power densities consistent with §146.
7. **People** sensible and latent gains must be based on the expected occupant density of the building and occupant activities. If ventilation requirements are based on a cfm/person basis, then people loads must be based on the same number of people as ventilation. Sensible and latent gains must be selected for the expected activities as listed in *ASHRAE Handbook, 1993, Fundamentals Volume*, Chapter 26, Table 3.
8. **Loads** caused by a process shall be based on actual information (not speculative) on the intended use of the building.
9. **Miscellaneous equipment loads** include such things as duct losses, process loads and infiltration and shall be calculated using design data compiled from one or more of the following sources:
   a. **Actual information** based on the intended use of the building; or
   b. Published data from manufacturer's technical publications and from technical societies, such as the ASHRAE Handbook, 1995 HVAC Applications Volume; or
   c. Other data based on the designer's experience of expected loads and occupancy patterns.
10. **Internal heat gains** may be ignored for heating load calculations.

11. A **safety factor** of up to 10 percent may be applied to design loads to account for unexpected loads or changes in space usage.

12. **Other loads** such as warm-up or cool-down shall be calculated using one of the following methods:

    a. A method using principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time; or

    b. The steady state design loads may be increased by no more than 30 percent for heating and 10 percent for cooling. The steady state load may include a safety factor of up to 10 percent as discussed above in Item 11.

    The combination of safety factor and other loads allows design cooling loads to be increased by up to 21 percent (1.10 safety x 1.10 other), and heating loads by up to 43 percent (1.10 safety x 1.30 other).

C. Fan Power Consumption (§144(c))

Maximum fan power is regulated in individual fan systems where the total power index of the supply, return and exhaust fans within the *fan system* exceed 25 horsepower at design conditions (see Section 4.1.2for definitions). A system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate systems. Included are all fans associated with moving air from a given space-conditioning *system* to the conditioned spaces and back to the source, or to exhaust it to the outdoors.

The 25 horsepower total criteria applies to:

1. All **supply and return fans** within the space-conditioning system that operate at peak load conditions.

2. All **exhaust fans at the system level** that operate at peak load conditions. Exhaust fans associated with economizers are not counted provided they do not operate at peak conditions.

3. **Fan-powered VAV boxes**, if these fans run during the cooling peak. This is always the case for fans in series type boxes. Fans in parallel boxes may be ignored if they are controlled to operate only when zone heating is required, and are normally off during the cooling peak.

4. **Elevator equipment room exhausts**, or other exhausts that draw air from a conditioned space, through an otherwise unconditioned space, to the outdoors.

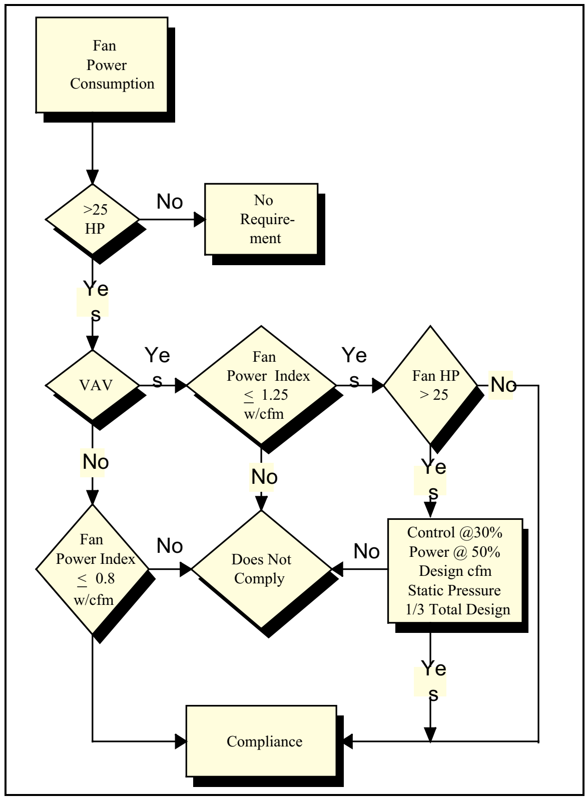
5. **Computer** room units.

   The criteria are applied individually to each space-conditioning system. In buildings having multiple space-conditioning systems, the criteria applies only to the systems having fans whose total demand exceeds 25 horsepower.

   Not included are fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building.

For the purposes of the 25 horsepower criteria, horsepower is the brake horsepower as listed by the manufacturer for the design conditions, plus any losses associated with the drive, including belt losses or variable frequency drive losses. If the brake horsepower is not known, then the nameplate horsepower should be used.

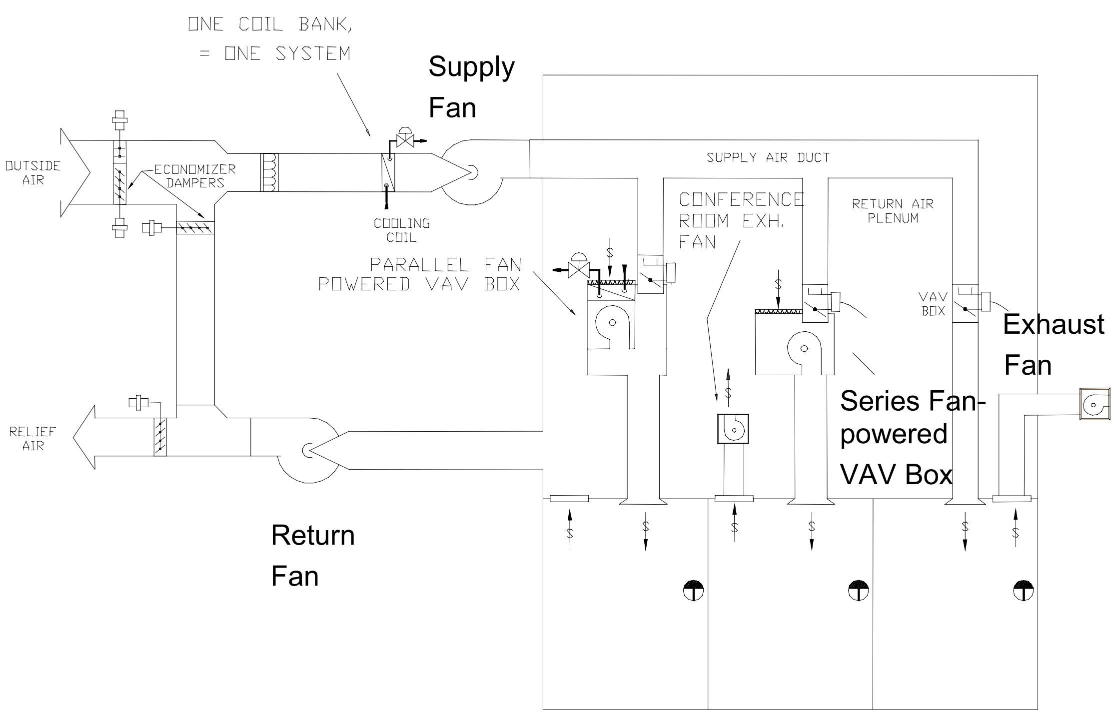
Figure 4-14– Fan Power Consumption Flowchart



Example 4-27 – Fan Power Limits

Question

In the system depicted below, which fans are included in the fan power criteria?



Answer

The fans included are those that operate during the design cooling load. These include the supply fan, the return fan, the series fan-powered VAV box(es) and the general exhaust fan. The parallel fan-powered VAV box(es) are not included as those fans only operate during a call for zone heating. The conference room exhaust fans are not included, as these spaces are not normally occupied.

Example 4-28– 25 HP Limit

Question

If a building has five zones with 15,000 cfm air handlers that are served by a common central plant, and each air handler has a 15 HP supply fan, does the 25 HP limit apply?

Answer

No. Each air handler, while served by a common central plant, is considered a separate space-conditioning system. Since the demand of each air handler is only 15 HP, the 25 HP criteria does not apply.

If drive losses are not known, the designer may assume that direct drive efficiencies are 1.0, and belt drives are 0.97. Variable speed drive efficiency should be taken from the manufacturer's literature; if it includes a belt drive, it should be multiplied by 0.97.

Total fan horsepower need not include the additional power demand caused solely by air treatment or filtering systems with final pressure drops of more than 1 inch water gauge (w.g.). It is assumed that conventional systems may have filter pressure drops as high as 1 inch w.g.; therefore only the horsepower associated with the portion of the pressure drop exceeding 1 inch, or fan system power caused solely by process loads, may be excluded.

Example 4-29– Filtration

Question

The space-conditioning system in a laboratory has a 30 percent filter with a design pressure drop at change out of 0.5 inch w.g., and an 80 percent filter with a design pressure drop of 1.2 inch w.g. The design total static pressure of the fan is 5.0 inch w.g. What percentage of the power may be excluded from the Watts/cfm calculation?

Answer

The total filter drop at change out (final pressure drop) is 0.5 inch + 1.2 inch = 1.7 inch w.g. The amount that may be excluded is 1.7 inch-1.0 inch = 0.7 inch w.g. The percentage of the horsepower that may be excluded is

0.7"/5.0" = 14%

If the supply fan requires 45 brake horsepower, the adjusted horsepower of the supply fan in the Watts/cfm calculation is

45 BHP x (1 - 14%) = 38.7 BHP

The horsepower of any associated return or exhaust fan is not adjusted by this factor, as the filters have no impact on these fans.

For buildings whose systems exceed the 25 horsepower criteria, the total space-conditioning system power requirements are:

1. **_Constant volume_** space-conditioning systems shall not exceed 0.8 watts per cfm of supply air.
2. **_Variable Air Volume (VAV)_** systems shall not exceed 1.25 Watts per cfm of supply air at design conditions.

   In addition, individual VAV fans with motors over 25 horsepower shall meet three requirements: 1) a mechanical or electrical variable speed drive fan motor; 2) vane axial fan with variable pitch blades; and 3) include controls that limit the fan motor demand to no more than 30 percent of design wattage at 50 percent design air volume.

Actual fan part load performance, available from the fan manufacturer, should be used to test for compliance with item 3) above. Figure 4-15 shows typical performance curves for different types of fans. As can be seen, both

airfoil fans and backward inclined fans using either discharge dampers or inlet vanes consume more than 30 percent power at 50 percent flow when static pressure set point is one-third of total design static pressure using certified manufacturer's test data. These fans will not normally comply with these requirements unless a variable speed drive is used.

The total system power demand is based on brake horsepower at design static and cfm, and includes drive losses and motor efficiency. If the motor efficiency is not known, values from Appendix B, Table B-8A & 8B, may be assumed.

The power demand is calculated on a system-by-system basis, and the maximum limit applies to each system individually. In other words, the power demands of separate systems cannot be averaged.

Example 4-30– VAV Bypass System

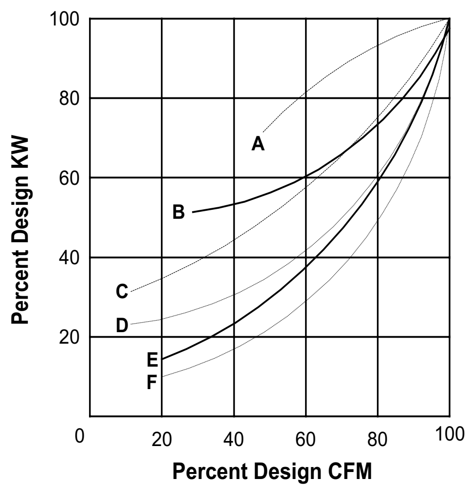
Question

What is the maximum allowed power consumption for the fans in a VAV bypass system?

Answer

A VAV bypass, while variable volume at the zone level, is constant volume at the fan level. If the total fan power demand of this system exceeds 25 HP, then the fan power may not exceed 0.8 Watts/cfm.

Figure 4-15– VAV Fan Performance Curve



A. Air foil or backward inclined centrifugal fan with discharge dampers

B. Air foil centrifugal fan with inlet vanes

C. Forward curved centrifugal fan with discharge dampers or riding curve

D. Forward curved centrifugal fan with inlet vanes

E. Vane-axial fan with variable pitch blades

F. Any fan with variable speed drive (mechanical drives will be slightly less efficient)

Example 4-31– Calculation of Fan Power

Question

What is the power consumption of a 20,000 cfm VAV system having an 18 BHP supply fan, a 5 BHP return fan, a 3 BHP economizer relief fan, a 2 HP outside air ventilation fan and a 1 HP toilet exhaust fan? Note that the exhaust and outside air ventilation fans are direct drive and listed in HP not BHP. The supply and return fans are controlled with variable frequency drives having an efficiency of 96 percent.

Answer

The economizer fan is excluded provided it does not run at the time of the cooling peak.

Power consumption is then based on the supply; return, outdoor and toilet exhaust fans. The ventilation fan is direct drive so its efficiency is 1.0. The supply and return fans have default drive efficiencies of 0.97. From Table B-8A & 8B, the assumed efficiencies of the motors are 88 percent and 85 percent for a 25 and 7.5 HP motor respectively. Fan power demand in units of horsepower must first be calculated to determine whether the requirements apply:

a. 18 BHP / (0.97 x 0.88 x 0.96) = 22.0 HP

b. 5 BHP / (0.97 x 0.85 x 0.96) = 6.3 HP

Total power consumption, adjusted for efficiencies, is calculated as:

22.0 HP + 6.3 HP + 2 HP + 1 HP = 31.3 HP

Since this is larger than 25 HP, the limitations apply. Watts per cfm is calculated as:

31.3 HP x 746 Watts/cfm/20,000 cfm = 1.17 Watts/cfm

The system complies because power consumption is below 1.25 Watts per cfm. Note that, while this system has variable frequency drives, they are not required by the *Standards* since each fan is less than 25 HP.

D. Space Conditioning Zone Controls (§144(d))

Each space-conditioning zone shall have controls that prevent:

1. **Reheating** of air that has been previously cooled by mechanical cooling equipment or an economizer.
2. **Recooling** of air that has been previously heated. This does not apply to air returned from heated spaces.
3. **Simultaneous heating and cooling** in the same zone, such as mixing or simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled, either by cooling equipment or by economizer systems.

These requirements do not apply to zones having:

1. **VAV controls**, as discussed in Section E. below;
2. **Special pressurization relationships** or cross contamination control needs. Laboratories are an example of spaces that might fall in this category.
3. **Site-recovered or site-solar** energy providing at least 75 percent of the energy for reheating, or providing warm air in mixing systems.
4. **Specific humidity requirements** to satisfy process needs.
5. **300 cfm or less** peak supply air quantity. This exception allows reheating or recooling to be used in small zones served by constant volume systems.

Example 4-32– Minimum VAV CFM

Question

What is the required minimum cubic feet per minute (cfm) for a 1000 square foot office having a design supply of 1100 cfm and eight people?

Answer

Based on reheat requirements, the minimum cfm should not exceed the larger of:

a. 1000 ft^2 x 0.4 cfm/ft^2 = 400 cfm; or

b. 1100 cfm x 30% = 330 cfm; or

c. 300 cfm

Based on reheat, airflow must be reduced to no more than 400 cfm.

Outdoor ventilation requirements are the larger of:

a. 1000 ft^2 x 0.15 cfm/ft^2 = 150 cfm; or

b. 8 people x 15 cfm/person = 120 cfm

Based on ventilation requirements, the airflow must be at least 150 cfm. The minimum ventilation rate must then be in the range below the reheat requirement and above the ventilation requirement, or 150 – 400 cfm.

If, instead, the space were a conference room holding 35 people, then the design outdoor ventilation rate would be 35 x 15 = 525 cfm. Since this is above the reheat requirement of 400 cfm, the minimum cfm must be 525 cfm, unless transfer air is taken from other spaces

E. VAV Zone Controls (§144(d) Exception No. 1

Prior to reheating, recooling or mixing air, the controls in VAV zones must be set to reduce the air supply to a minimum. The minimum volume shall be no greater than the largest of:

1. 30 percent of the peak supply volume; or
2. 0.4 cfm per square foot of conditioned floor area of the zone; or
3. 300 cfm.

Note however, that §121(c) requires that the minimum rate of outdoor ventilation air calculated in §121(b)2 be supplied to each space at all times when the space is usually occupied. The allowable minimum airflow for a VAV box then usually falls in a range limited by the ventilation requirements at the lower end, and the reheat requirements at the upper end. In some cases, however, the required ventilation rate may be larger than the rate required for reheat. In this case, the required rate for reheat is the ventilation rate unless other provisions are made to supply ventilation air.

F. Economizers (§144(e))

An economizer must be fully integrated and must be provided for each individual cooling space-conditioning system that has a design supply capacity over 2,500 cfm and a total cooling capacity over 75,000 Btu/hr. The economizer may be either:

1. An ***air economizer*** capable of modulating outside air and return air dampers to supply 100 percent of the design supply air quantity as outside air. (For Prescriptive Compliance, samples of integrated economizers that meet this requirement are: fixed drybulb, differential drybulb, fixed enthalpy, or differential enthalpy); or
2. A ***water economizer*** capable of providing 100 percent of the expected system cooling load at outside air temperatures of 50°F dry-bulb and 45°F wet-bulb and below.

Depicted below in Figure 4-16 is a schematic of an air-side economizer. All air side economizers have modulating dampers on the return and outdoor air streams. To maintain acceptable building pressure, systems with airside economizer must have provisions to relieve or exhaust air from the building. In Figure 4-16 three common forms of building pressure control are depicted: Option 1 barometric relief, Option 2 a relief fan generally controlled by building static pressure, and Option 3 a return fan often controlled by tracking the supply.

Figure 4-17 depicts an integrated air-side economizer control sequence. On first call for cooling the outdoor air damper is modulated from minimum position to 100% outdoor air. As more cooling is required, the damper remains at 100% outdoor air as the cooling coil is sequenced on.

Graphics of water-side economizers are presented in the Design Concepts section at the beginning of this chapter.

Figure 4-16– Air-Side Economizer Schematic

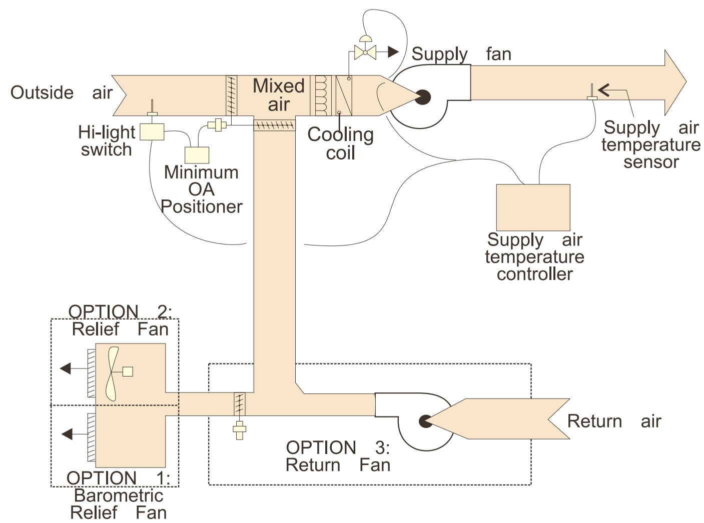
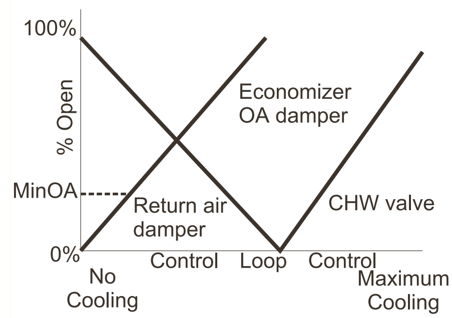


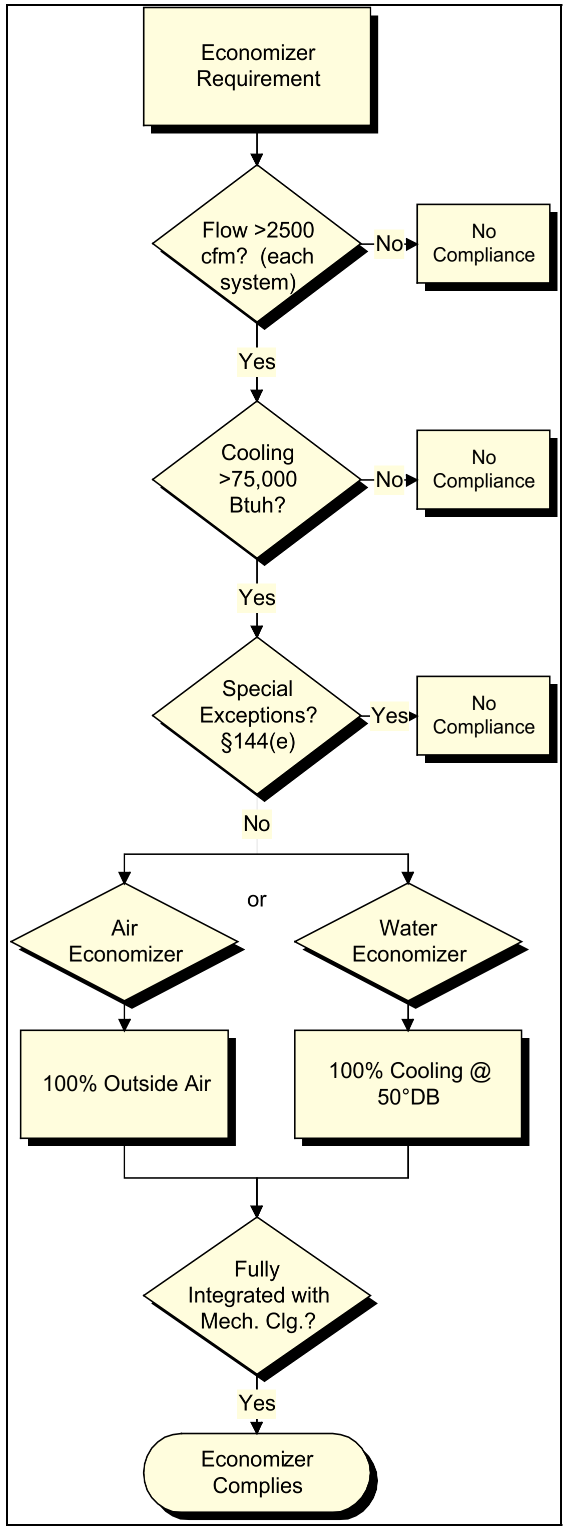
Figure 4-17– Typical Air-Side Economizer Control Sequencing



Economizers are not required where:

1. **Outside air filtration and treatment** for the reduction and treatment of unusual outdoor contaminants make compliance infeasible. This must be demonstrated to the satisfaction of the enforcement agency.
2. **Increased overall building energy use** results. This may occur where economizers adversely impact other systems, such as humidification, dehumidification or supermarket refrigeration systems.

Figure 4-18– Economizer Flowchart



3. Systems serving **high-rise residential living quarters** and **hotel/motel guest rooms**. Note that these buildings typically have systems smaller than 2,500 cfm, and also have provisions for natural ventilation.

4. If **cooling capacity** is less than or equal to 75,000 Btu/hr, or **supply airflow** is less than or equal to 2,500 cfm.

5. For unitary air-conditioners and heat pumps whose rated efficiency meets or exceeds the efficiency levels in Table 4-5 (Tables 1-X1 in the *Standards* - Unitary Air-conditioners) and Table 4-6 (1-X2 in the *Standards* - Unitary Heat Pumps) present trade-off efficiency levels by climate zone (left column) and equipment size category (top row). Table cells marked with "N/A" for "not applicable" represent combinations of climate zones and size categories for which there is no trade-off available (i.e. and air-side economizer is always required).

Table 4-5 - [Table 1-X1 of the Standard] – Economizer Tradeoff Table for Electrically Operated Unitary Air Conditioners

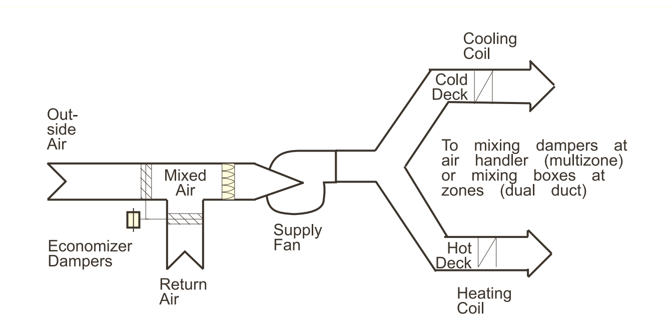
	Energy Efficiency Ratio (EER)			
	Size Category			
Climate Zone	**>=760,000**	**>=240,000 and <760,000**	**>=135,000 and <240,000**	**>=65,000 and <135,000**
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	11.9	12.2	12.4	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	11.9	12.2	12.4	N/A
9	11.6	11.9	12.1	N/A
10	11.4	11.7	11.9	12.4
11	11.5	11.8	12.0	N/A
12	11.7	12.0	12.2	N/A
13	11.2	11.5	11.7	12.3
14	11.7	12.0	12.2	N/A
15	10.0	10.4	10.6	11.3
16	N/A	N/A	N/A	N/A

Table 4-6 - [Table 1-X2 of the Standard] – Economizer Tradeoff Table for Electrically Operated Heat Pumps

	Energy Efficiency Ratio (EER)		
	Size Category		
Climate Zone	**>=240,000**	**>=135,000 and <240,000**	**>=65,000 and <135,000**
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	11.7	12.1	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	12.3	N/A	N/A
8	11.7	12.0	N/A
9	11.3	11.7	12.5
10	11.1	11.5	12.3
11	11.3	11.6	12.4
12	11.5	11.8	N/A
13	10.9	11.3	12.1
14	11.5	11.8	N/A
15	9.8	10.1	11.1
16	N/A	N/A	N/A

If an economizer is required, it must be designed and equipped with controls that do not increase the building heating energy use during normal operation. This prohibits the application of single-fan dual-duct VAV systems using the Prescriptive Approach of compliance (see Figure 4-19). In this system the operation of the economizer to precool the air entering the cold deck also precools the air entering the hot deck and thereby increases the heating energy. The exception is when at least 75 percent of the annual heating is provided by site-recovered or site-solar energy (§144(e)2.A).

Figure 4-19– Single-Fan Dual-Duct System



The economizer controls must also be fully *integrated* into the cooling system controls so that the economizer can provide partial cooling even when mechanical cooling is required to meet the remainder of the load §144(e)2.B).

The requirement that economizers be designed for concurrent operation is not met by some popular water economizer systems, such as those which use the chilled water system to convey evaporative-cooled condenser water for “free” cooling. Such systems can provide 100 percent of the cooling load, but when the point is reached where condenser water temperatures cannot be sufficiently cooled by evaporation, the system controls throw the entire load to the mechanical chillers. Because this design cannot allow simultaneous economizer and refrigeration system operation, it does not meet the requirements of this section.

Air-side economizers are required to have high-limit shut-off controls that comply with Table 4-7 (Table 1-X3 of the *Standards*). This table has four columns:

1. The first column identifies the high limit control category. There are five categories representing enthalpy and dry-bulb controls (fixed and differential and the electronic enthalpy controller.

2. The second column represents the California Climate Zone. “All” indicates that this control type complies in every California climate.

3. The third and forth columns present the high-limit control setpoints required.

Fixed enthalpy controls are prohibited in Climate Zones 01, 02, 03, 05, 11, 13, 14, 15 & 16. In these mild climates the enthalpy in the return air varies throughout the year and cannot be accurately represented by a fixed setpoint.

Table 4-7- [Table 1-X3 of the Standard] – Air Economizer High Limit Shut Off Control Requirements

Device Type	Climate Zones	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed Dry Bulb	1, 2, 3, 5, 11, 13, 14, 15 & 16	$T_{OA} > 75$ F	Outside air temperature exceeds 75 F
	4, 6, 7, 8, 9, 10 & 12	$T_{OA} > 70$ F	Outside air temperature exceeds 70 F
Differential Dry Bulb	All	$T_{OA} > T_{RA}$	Outside air temperature exceeds return air temperature
Fixed Enthalpy[a]	4, 6, 7, 8, 9, 10 & 12	$h_{OA} > 28$ Btu/lb[b]	Outside air enthalpy exceeds 28 Btu/lb of dry air[b]
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outside air temperature/RH exceeds the "A" set-point curve[c]
Differential Enthalpy	All	$h_{OA} > h_{RA}$	Outside air enthalpy exceeds return air enthalpy

[a] Fixed Enthalpy Controls are prohibited in climate zones 1, 2, 3, 5, 11, 13, 14, 15 & 16.

[b] At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75 F and 50% relative humidity. As an example, at approximately 6000 ft elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.

[c] Set point "A" corresponds to a curve on the psychometric chart that goes through a point at approximately 75 F and 40% relative humidity and is nearly parallel to dry bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.

Air economizers, water economizers and integrated controls are discussed in more detail in the Design Concepts section at the beginning of this Chapter.

Example 4-33– Water-Side Economizer Tower Sizing

Question

If my design conditions are 94°Fdb/82°Fwb can I use my design cooling loads to size an water-side economizer?

Answer

No. The design cooling loads must be rerun with the outdoor air temperature set to 50°Fdb/45°Fwb. The specified tower must be checked to determine if it has adequate capacity at this lower load and wet-bulb condition.

Example 4-34– Strainer-Cycle Water Side Economizer

Question

Will a strainer cycle water-side economizer meet the Prescriptive Economizer Requirements? (Refer to Figure 4-4.)

Answer

No. It cannot be integrated to cool simultaneously with the chillers.

Example 4-35– Economizer Trade-Off Method

Question

Does a 12 ton packaged HVAC unit in climate zone 10 need an economizer?

Answer Yes. However it can waive that requirement per exception 5 to 144(e)1 if its efficiency is greater than or equal to an EER of 11.9. (Refer to Table 4-5)

G. Supply-Air Temperature Reset Control (§144(f))

Mechanical space-conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls must be capable of resetting the supply-air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

For example, if the design supply temperature is 55°F and the design room temperature is 75°F, then the difference is 20°F, and 25 percent is 5°F. Therefore, the controls must be capable of resetting the supply temperature from 55°F to 60°F.

Air distribution zones that are likely to have constant loads, such as interior zones, shall have air flow rates designed to meet the load at the fully reset temperature. Otherwise, these zones may prevent the controls from fully resetting the temperature, or will unnecessarily limit the hours when the reset can be used.

Supply air reset is usually required for VAV reheat systems. It is also required for constant volume systems with reheat justified on the basis of special zone pressurization relationships or cross-contamination control needs.

Supply-air temperature reset is not required when:

1. The zone(s) must have specific humidity levels required to meet process needs; or

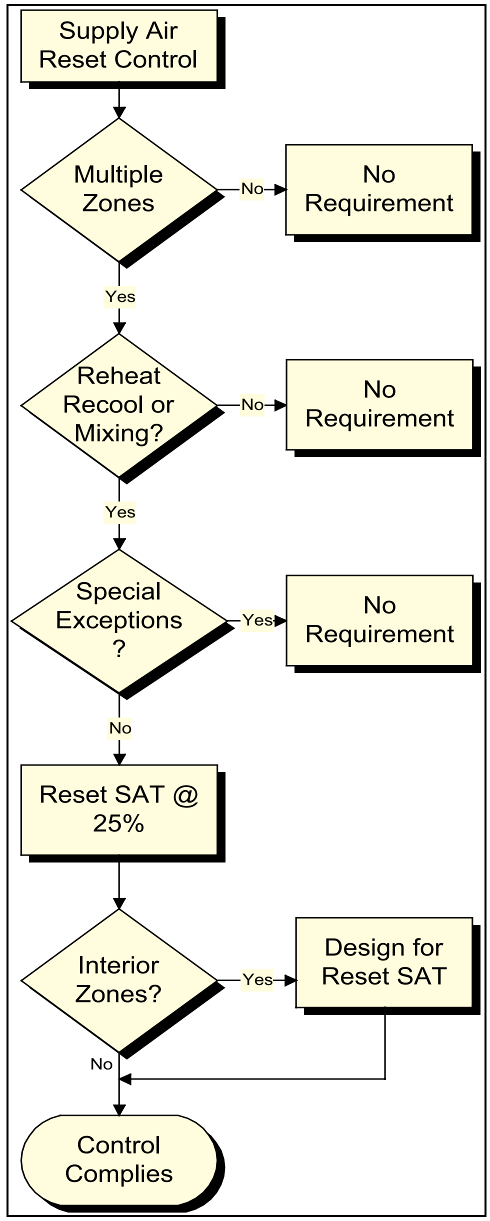
2. Where it can be demonstrated to the satisfaction of the enforcement agency that supply air reset would increase overall building energy use; or

3. The space-conditioning zone has controls that prevent reheating and recooling and simultaneously provide heating and cooling to the same zone; or

4. 75 percent of the energy for reheating is from *site-recovered* or *site solar* energy source; or

5. The zone has a peak supply air quantity of 300 cfm or less.

Figure 4-20– Supply Air Reset Controls Flowchart



H. Electric-Resistance Heating (§144(g))

The *Standards* strongly discourage the use of electric-resistance space heat. Electric-resistance space heat is not allowed in the Prescriptive Approach except where:

1. **Site-recovered** or **site-solar** energy provides at least 60 percent of the annual heating energy requirements; or
2. A **heat pump** is supplemented by an electric-resistance heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load at the design outdoor temperature, determined in accordance with these *Standards*; or
3. The **total capacity** of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building; or

4. The total capacity of all electric-resistance heating systems serving the building, excluding those that supplement a heat pump, is **no more than 3 kW**; or
5. An electric-resistance heating system serves an entire building that:
   a. Is not a high-rise residential or hotel/motel building; and
   b. Has a conditioned floor area no greater than 5,000 square feet; and
   c. Has no mechanical cooling; and
   d. Is in an area where natural gas is not currently available and an extension of a natural gas system is impractical, as determined by the natural gas utility.
6. In alterations where the existing mechanical systems use electric reheat (when adding variable air volume boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application.
7. In an addition where the existing variable air volume system with electric reheat is being expanded the added capacity cannot exceed 50 percent of the existing installed electric reheat capacity under any one permit.

The *Standards* in effect allow a small amount of electric-resistance heat to be used for local space heating or reheating (provided reheat is in accordance with these regulations).

Example 4-36– Heat Pump Sizing

Question

If a heat pump is used to condition a building having a design heating load of 100,000 Btu/hr at 35°F, what are the sizing requirements for the compressor and heating coils?

Answer

The compressor must be sized to provide at least 75 percent of the heating load at the design heating conditions, or 75,000 Btu/hr at 35°F. The *Standards* do not address the size of the resistance heating coils. Normally, they will be sized based on heating requirements during defrost.

I. Heat Rejection System Controls (§144(h))

The fans on cooling towers, closed-circuit fluid coolers, air-cooled condensers and evaporative condensers are required to have speed control except as follows:

1. Fans powered by motors smaller than 7.5 hp
2. Heat rejection devices included as an integral part of the equipment listed in *Standards* Tables 1-C1 through 1-C4. This includes unitary air-conditioners, unitary heat pumps, packaged chillers and packaged terminal heat pumps.
3. Condenser fans serving multiple refrigerant circuits or flooded condensers.
4. Up to 1/3 of the fans on a condenser or tower with multiple fans where the lead fans comply with the speed control requirement.

Where applicable, two-speed motors, pony motors or variable speed drives can be used to comply with this requirement.

Example 4-37– Heat Rejection System Controls

Question

A chilled water plant has a three cell tower with 10 hp motors on each cell. Are speed controls required?

Answer

Yes. At minimum the designer must provide 2-speed motors, pony motors or variable speed drives on two of the three fans for this tower.

J. Service Water Heating (§145)

A service water-heating system is considered to comply with the Prescriptive Requirements when all Mandatory Requirements are met. The *Standards* for low-rise residential buildings have been adopted for service water-heating systems in high-rise residential buildings (see Appendix H).

4.2.3 Performance Approach

Under the Performance approach, the energy use of the building is modeled using a computer program approved by the *Energy Commission*. This section presents some basic details on the modeling of building mechanical systems. *Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program*. All computer programs, however, are required to have the same basic modeling capabilities.

The details of how to model the mechanical systems and components are included in Section 6.1. Specific application scenarios are contained in Section 6.1.4.

A. Compliance With a Computer Method

Each approved computer method automatically generates an *energy budget* by calculating the annual energy use of the standard design, a version of the proposed building incorporating all the Prescriptive features.

A building complies with the *Standard* if the predicted source *energy use* of the proposed design is the same or less that the annual *energy budget* of the standard design. The energy budget includes a space-conditioning budget, lighting budget and water-heating budget.

Source energy use defines the energy use of a building by converting the calculated energy consumption into *source energy.* A table of *source energy multipliers* is found in §102*.* Source energy multipliers adjust the calculated energy consumption of a building to account for the energy content of different fuels and inefficiencies in generating and distributing electricity.

The budget for space conditioning of the proposed building design varies according to the following specific characteristics:

- Orientation
- Conditioned floor area
- Conditioned volume
- Gross exterior surface area
- Space-conditioning system type
- Occupancy type
- Climate zone

Assumptions used by the computer methods in generating the energy budget are explained in the *Alternative Calculation Methods Approval Manual* and are based on features required for Prescriptive compliance.

B. Modeling Mechanical System Components

All alternative computer programs have the capability to model various types of HVAC systems. In central systems, these modeling features affect the system loads seen by the plant. This is done by calculating the interactions between envelope, mechanical and electrical systems in the building and summarizing the energy required by the mechanical system to maintain space conditions.

For a complete description of how to model mechanical system components, refer to the compliance supplement for the approved computer program being used to demonstrate compliance.

4.2.4 Alterations/Additions

When heating, cooling or service water heating are provided for an alteration or addition by expanding an existing system, that existing system need not comply with Mandatory measures or compliance requirements. However, any altered component must meet all applicable Mandatory measures.

When existing heating, cooling, or service water heating systems or components are moved within a building, the existing systems or components need not comply with Mandatory measures nor with the Prescriptive or Performance compliance requirements.

4.2.5 Application to Major System Types

This section summarizes the Mandatory, Prescriptive, and Performance Measures as they apply to the major mechanical system designs as used in California. The systems presented are:

- Packaged air conditioner with gas furnace or heat pump
- Packaged VAV reheat
- Built-up VAV reheat
- Built-up single-fan dual duct VAV
- Built-up or packaged dual-fan dual-duct VAV
- Packaged terminal air conditioner with gas furnace or heat pump
- Four-pipe fan-coil system with central plant
- Hydronic heat pump with central plant

For each of these systems, the Mandatory, Prescriptive and Performance Measures are described. Limitations imposed by the *Standards*, if any, are discussed together with mitigating measures that can be taken.

Although there are more variations and combinations of systems than are covered here, this section can be used as a guide for other systems. Where there are ambiguities, the designer should refer directly to the Sections describing the Mandatory and Prescriptive requirements.

To avoid excessive redundancy, this section contains the requirements that normally apply to systems. There are various exceptions to these requirements that are not included here; the designer should refer to the sections detailing the Mandatory, Prescriptive and Performance Requirements for these exceptions.

In the following Section 4.2.5 A-H, Mandatory requirements are designated by [M], Prescriptive by [P], and Performance by [Pf].

A. Packaged Air Conditioner with Gas Furnace or Heat Pump

A packaged air conditioner with gas furnace is a self-contained system that uses a gas furnace to heat the supply air, and a direct expansion coil and compressor to cool the supply air. The package also includes a supply fan, condenser fan(s) and possibly return or exhaust fans. The compressor and outside air heat exchanger may be either integral to the unit, or remote.

Heating may alternatively be provided with a heat pump. In this case, controls and changeover valves are incorporated so that the compressor and heat exchangers can alternately provide heating or cooling. This system is commonly called a packaged heat pump.

The system is most commonly used in a single zone configuration, but subzone VAV configurations with or without reheat are also used. Where VAV zoning exists, VAV requirements also apply.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A[P]. Allowable safety factors and pick-up factors may be applied.

2. Any equipment listed in Appendix B, Table B-9, shall comply with the **listed efficiencies** [M].

3. **Fan power consumption** must be no more than 0.8 Watts/cfm of supply air for constant volume systems (Section 4.2.2C[P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning system that operate during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any space-conditioning system having fans totaling less than 25 HP.

4. **Ventilation** shall be in accordance with Section 4.2.1E- G [M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.
5. A fully integrated **economizer** with compliant high limit switch controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F) [P]. If the unit meets or exceeds the efficiency requirements of Table 4-5 or Table 4-6 the economizer requirement is waived. The designer should refer to Section 4.2.2F for the other exceptions.

6. Demand ventilation controls are required for units with 3,000 cfm or greater of design outdoor air serving high-density spaces (less than 10 ft² /person) [M].

7. **Electric-resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P].

   When a heat pump is specified with supplementary resistance heaters, the heat pump capacity using only the compressor must be at least 75 percent of the design heating load at design conditions per Section 4.2.2H [P].

   The designer should refer to Section 4.2.2H for the exceptions.

8. **Zone Controls** shall be in accordance with Section 4.2.1G[M] and Section 4.2.2D and E [P].

   For single zone systems, a **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F dead band between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (Section 4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to On.

   For constant volume systems with subzones, the system must be designed and provided with controls to prevent **reheating** of cooled or economizer air 4.2.1G[P]. Variable volume systems have different requirements described in Section 4.2.2E.

9. **System controls** shall be in accordance with Section 4.2.1G [M], and Section 4.2.2D and E [P]. The requirements are as follows:

   An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** (Section 4.2.1F)[M]. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in not more than an hour, whichever is less.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   If the system serves multiple zones, the controls must include a **supply air temperature reset** function per Section 4.2.1G [P].

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down.

   When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other per Section 4.2.1G[M]. Since most packaged units serve areas smaller than this, isolation can usually be accomplished by using automatic time switches for each unit or group of units.

10. **Heat pump thermostats and controls** must meet all of the requirements in items 7 and 8 above, and in addition must have controls [M]:

    a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

    b. In which the cut-on and cut-off temperatures for compression heating are higher than the temperatures for supplementary heating.

The controls may allow supplementary heating during:

   a. Defrost; and

   b. Transient periods such as start-up or raising the room thermostat setpoint if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

11. Ducts must be installed, sealed and insulated (Section 4.2.1I) [M] in compliance with §124 of the *Standards*.

B. Packaged VAV Reheat

A packaged variable air volume (VAV) system consists of a self-contained unit that uses a direct expansion coil and compressor(s) to cool the supply air, an optional heating section, and zones with individual VAV boxes. The package also includes a supply fan, condenser fan(s) and possibly return or exhaust fans. The compressor and condenser are normally integral to the system. The heating section may be either a gas furnace, a hot water coil, or a heat pump.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A[P]. Allowable safety factors and pick-up factors may be applied.

2. Any equipment listed in Table B-9 of Appendix B shall comply with the **listed efficiencies** [M].

3. **Design fan power consumption** must be no more than 1.25 Watts/cfm of supply air (Section 4.2.2C)[P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning system that operates during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any system having fans totaling less than 25 horsepower (HP).

If the system has fan-powered VAV boxes, the VAV box fan power is included if these fans run during the cooling peak.

a. **Series box fans** must run continuously during occupied hours, so fan power is always included. If the box is sized to move more than the primary design supply quantity (induction ratio greater than 1.0), then the amount of additional plenum air supplied may be added to the total system supply cfm. Otherwise, the supply cfm is determined solely on the basis of the main supply fan.

Example 4-38– Series Fan-Powered Box

Question

How is the contribution to system fan power calculated for a series fan-powered VAV box having a primary air supply of 1,000 cfm, a total fan supply of 1,200 cfm, and a 450 watt fan?

Answer

Supply cfm cannot be double-counted. Since 1,000 cfm is being supplied by the main system fans, 1,200-1,000 = 200 cfm is contributed by the box fan, and may be added to the total system cfm.

Total system fan power is increased by 450 watts.

b. **Parallel box fans** may or may not run continuously, depending on the designer's intent. If the fan runs only during periods of zone heating, then box cfm and power are excluded. If the fan runs continuously, then both fan airflow and power are taken into account.

Example 4-39– Parallel Fan-Powered Box

Question

How is the contribution to system fan power calculated for a parallel fan-powered box having a primary air supply of 1,000 cfm, a parallel fan supply of 300 cfm and a 1/15 HP motor? The box is part of a cold air distribution system (45 °F primary supply temperature), and runs continuously to temper the supply air.

Answer

Since the 300 cfm contributed by the parallel fan is in addition to the primarily supply, total system supply is increased by 300 cfm.

The efficiency of a 1/15 horsepower motor is approximately 48 percent (Table B-8) and the direct drive efficiency is 1.0. Fan power is therefore:

(1/15 HP x 746 W/HP) / 0.48 = 104 watts which is added to the total system power.

If instead the fan were controlled to operate only during zone heating, then both cfm and power would be excluded from the system calculations.

4. **Operating fan power consumption** of individual fans with motors 25 horsepower and larger shall be limited to no more than 30 percent of the design wattage at 50 percent design air volume (Section 4.2.2C) when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data. Mechanisms and controls shall be provided for this purpose. Normally, fans of this size are either of the airfoil or vane-axial design. Airfoil fans riding the curve, using discharge dampers, or inlet vanes will not normally comply. Vane-axial fans require variable pitch

blades to comply. Alternatively, a variable frequency drive can be used with either type of fan. Other fans, such as variable scroll fans may comply; manufacturer's data must be consulted.

5. **Ventilation** shall be in accordance with Section 4.2.1D - E [M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

This quantity of outdoor air must be delivered at all times of occupancy; provisions must be incorporated in the system to maintain this constant ventilation rate as the supply airflow rate decreases in response to low cooling loads. Conference rooms or other spaces having dense but intermittent occupancy levels may require fan-powered VAV boxes, transfer fans or other mechanisms to accommodate their high ventilation requirements through the use of transfer air.

6. A fully integrated **economizer** with compliant high limit switch controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2E) [P]. If the unit meets or exceeds the efficiency requirements of Table 4-5 the economizer requirement is waived. If required, the economizer must be controlled such that its use does not overcool the mixed air and cause heating energy or reheat energy to increase.

Economizers are not required in systems serving high-rise residential living quarters and hotel/motel guest rooms.

7. **Electric resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P]. If supply air heating/cooling is provided by a heat pump specified with supplementary resistance heaters, the heat pump capacity using only the compressor must be at least 75 percent of the design-heating load at design conditions [P].

8. **VAV Zone Controls** shall be in accordance with Section 4.1.2G and 4.1.2H [M], and Section 4.2.2E[P].

For each zone, a thermostat must be provided to control the supply of heating and cooling [M]. Heating and cooling setpoints must be individually adjustable. The heating setpoint must be adjustable down to 55°F or lower (if reheat is provided), and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints.

If no reheat is used, then a single setpoint zone thermostat may be used.

Prior to reheating, recooling or mixing air, the controls must reduce the air supply to a flow no greater than the largest of [M]:

a. 30 percent of the peak supply volume; or

b. 0.4 cfm per square foot of conditioned floor area of the zone; or

c. 300 cfm

In addition, the minimum supply airflow must be equal to at least the minimum amount required to meet the ventilation requirements [M], unless some other means is provided to ensure outdoor ventilation at all times. Normally, the required minimum airflow will fall in a range bounded at the lower end by the ventilation requirement, and at the higher end by the reheat flow requirement. If the minimum ventilation requirement is larger than the reheat requirement, then the reheat requirement is the same as the ventilation requirement.

The VAV box controls should be able to measure the airflow rate and control the supply so that at least the minimum supply airflow rate is maintained at all times [M]. For this reason, VAV controls should of the **pressure independent** type; pressure dependent controls do not measure flow, and therefore should not be used.

Zonal VAV controls that reduce the airflow below the minimum ventilation rate more than 5 out of every 60 minutes cannot be used. For this reason, systems that alternately provide heated and cooled air to different zones through the same duct work cannot be used unless provisions are made to maintain the minimum ventilation rates (Section 4.2.2G) [M].

9. **System controls** shall be in accordance with Section 4.1.2H[M], 4.2.2D[P], and 4.2.2E[P]. The requirements are as follows:

An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A 4-hour manual override must be accessible to the occupants for off-hours operation.

The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1F. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in no more than an hour, whichever is less.

The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

The controls must include a **supply air temperature reset** function per Section 4.2.2G[P]. Air flow rates to **interior zones** or other zones with relatively constant loads should be based on the fully reset temperature.

When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down or set back independently of each other per Section 4.2.1G[M].

Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down [M]. In addition, if ventilation air is provided through these dampers, the dampers must be controlled so that the minimum ventilation quantities are maintained during all times of occupancy [M]. The designer should refer to Section 4.2.1H for more information.

10. Systems using **heat pumps** for central heating must have controls [M]:

a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

b. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

The controls may allow supplementary heating during:

Defrost; and

ii. Transient periods such as start-up if the controls provide preferential rate control, intelligent recovery, staging, ramping, or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

11. **Ducts** must be installed, sealed and insulated per Section 4.2.1I[M]. Ducts must be insulated in compliance with §124 of the *Standards*. Higher insulation levels are encouraged, particularly when duct runs are very long, or run through unconditioned spaces.

12. Piping for unit hot water coils or reheat coils must be insulated in accordance with Section 4.2.1H[M].

C. Built-up VAV Reheat

Built-up VAV systems are thermodynamically similar to package VAV systems. While a packaged system is usually delivered and installed as a unit on the roof, a built-up system consists of individual components that are delivered to the site separately and are assembled within mechanical rooms. Supply air in a built-up system is commonly conditioned using hot and chilled water coils, although DX coils may also be used. A central boiler/chiller plant provides the working fluids to one or more air handling systems.

Hybrids of built-up and packaged systems also exist. For example a packaged unit may use a hot water coil for heating that in turn is supplied with fluid from a central boiler. A built-up system may use a packaged air handler consisting of a fan, hot and chilled water coils, a filter section, and a mixing box all in one unit.

Because packaged and built-up VAV systems are thermodynamically similar, most of the requirements are the same. The following are the additional requirements for built-up systems:

1. The **efficiency** of boilers and chillers shall be in accordance with Table B-9 in Appendix B [M]. Centrifugal chillers designed to operate at other than ARI conditions need to comply with the trade-off Tables 1-C8, 1-C9 and 1-C10. See Example 4.3.5.

2. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing, restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A). The compliance program automatically assign constant volume pumps as though they are cooling tower pumps. Variable volume pumps are modeled with chiller in the compliance programs so they will vary with chiller capacity. The compliance program automatically assigns the pumps to standard and proposed designs allocating the pump type to the appropriate part of the model. For multiple chillers, pumps are individually assigned to each chiller (fixed pumps are treated as a cooling tower pump assigned to each chiller) for both the standard and proposed designs.

3. Cooling tower fans over 5 hp must have two-speed, pony motors or variable speed drives [P].

D. Built-up Single-fan Dual-duct VAV

A single-fan, dual-duct VAV system consists of a blow-through fan whose discharge splits into a “hot deck” with a heating coil and a “cold deck” with a cooling coil. A pair of ducts delivers heated and cooled air to VAV mixing boxes in each zone. Each box modulates the flow of hot and cold air to its zone to maintain space temperature setpoint. The system will usually have an economizer, and return/exhaust fans may also be incorporated.

The original versions of this system were constant volume; heated and cooled air were proportionately mixed to maintain space temperature while the total volume of air delivered to the space remained constant. These constant-volume systems wasted large amounts of heating and cooling energy in the mixing process, and are effectively prohibited by the *Standards* with few exceptions.

The Prescriptive *Standards* require that dual-duct systems be variable-volume; cooling air must be reduced to a minimum before heating air is allowed to mix. They also prohibit the application of air-side economizers on single-fan dual-duct systems as the operation of the economizer will increase the hot-deck heating energy.

As with VAV systems, hybrids of packaged and built-up dual duct systems exist. For example a packaged unit may use a hot water coil for heating, which in turn is supplied with fluid from a central boiler. A built-up system may use a packaged air handler consisting of a fan; hot and chilled water coils, a filter section and a mixing box all in one unit.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.

2. The **efficiency** of boilers and chillers shall be in accordance with Appendix B, Table B-9 [M]. Centrifugal chillers designed to operate at other than ARI conditions need to comply with the trade-off Tables 1-C8, 1-C9 and 1-C10. See Section 4.2.1A and 4.2.1B.

3. **Design fan power consumption** must be no more than 1.25 Watts/cfm of supply air(Section 4.2.2C) [P]. The limit applies to the sum of the power of all supply, return, and exhaust fans in the space-conditioning system that operate during the peak design period, including toilet exhaust fans. This requirement does not apply to any fans that do not operate at peak, such as economizer exhaust fans. The limit does not apply to any system having fans totaling less than 25 horsepower.

4. **Operating fan power consumption** of individual fans with motors 25 horsepower and larger shall be limited to no more than 30 percent of the design wattage at 50 percent design air volume when static pressure set point equals 1/3 of the total design static pressure, based on certified manufacturer's test data (Section 4.2.2C) [P]. Mechanisms and controls shall be provided for this purpose.

Normally, fans of this size are either of the airfoil or vane-axial design. Airfoil fans riding the curve, using discharge dampers, or inlet vanes, will not normally comply. Vane-axial fans require variable pitch blades to comply. Alternatively, a variable frequency drive can be used with either type of fan. Other fans, such as variable scroll fans may comply; manufacturer's data must be consulted.

5. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A). See Section 4.2.5C.

6. **Ventilation** shall be in accordance with Section 4.2.1C through F[M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

This quantity of outdoor air must be delivered at all times of occupancy; provisions must be incorporated in the system to maintain this constant ventilation rate as the supply airflow rate decreases in response to low cooling loads. The designer should refer to Section 4.2.1A for additional guidance.

Conference rooms, or other spaces having dense but intermittent occupancy levels, may require fan-powered VAV boxes, transfer fans or other mechanisms to accommodate their high ventilation requirements through the use of transfer air.

Single-Fan Dual Duct VAV systems cannot meet the Prescriptive air-side economizer requirements. They must either employ an integrated water-side economizer or use the Performance Approach. Economizers are not required in systems serving high-rise residential living quarters and hotel/motel guest rooms.

7. **Electric resistance heating** for reheat, etc. is prohibited in most circumstances (Section 4.2.2H) [P].

8. **VAV Zone Controls** shall be in accordance with Section 4.2.1G[M] and Section 4.2.2D and E[P].

For each zone, a **thermostat** must be provided to control the supply of heating and cooling [M].

Heading and cooling setpoints must be individually adjustable. The heating setpoint must be adjustable down to 55°F or lower (if reheat is provided), and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints.

Prior to reheating, recooling or mixing air, the controls must reduce the air supply to a flow no greater than the largest of [M]:

a. 30 percent of the peak supply volume; or

b. 0.4 cfm per square foot of conditioned floor area of the zone; or

c. 300 cfm

In addition, the minimum supply airflow must be equal to at least the minimum amount required to meet the ventilation requirements [M], unless some other means is provided to ensure outdoor ventilation at all times. Normally, the required minimum airflow will fall in a range bounded at the lower end by the ventilation requirement, and at the higher end by the reheat requirement. If the ventilation requirement is larger than the reheat flow requirement, then the reheat flow requirement is the same as the ventilation requirement.

9. **System controls** shall be in accordance with Section 4.2.1F and 4.2.1G[M], 4.2.2D[P], and 4.2.2E[P]. The requirements are as follows:

An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes in not more than an hour, whichever is less.

The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

The controls must include a **supply air temperature reset** function per Section 4.2.2G[P]. Both the hot deck and cold deck must incorporate the reset function. The controls should be capable of fully resetting the hot deck temperature from maximum design supply temperature down to return air temperature. Air flow rates to **interior zones** or other zones with relatively constant loads should be based on the fully reset temperature.

A **mixed air temperature reset** should be included to minimize the impact of the economizer on the hot deck energy usage. This reset may be sequenced with the cold deck reset, or be reset on the basis of outdoor air temperatures or representative zone temperatures.

When a unit serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down or set back independently of each other per Section 4.2.1G [M].

Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down [M]. In addition, if ventilation air is provided through these dampers, the dampers must be controlled so that the minimum ventilation quantities are maintained during all times of occupancy [M]. The designer should refer to Section 4.2.1H for more information.

10. Cooling tower fans over 5 hp must have two-speed, pony motors or variable speed drives [P].

11. Ducts must be installed, sealed and insulated per Section 4.2.1J[M].

12. **Piping** for unit hot water coils or reheat coils must be insulated in accordance with Section 4.2.1I[M].

E. Dual-Fan Dual-Duct VAV

A dual-fan dual-duct VAV system is similar to a single-fan dual-duct VAV system except that the hot and cold decks each have their own fan . This allows the hot deck to take air directly from the return while the cold deck is using economizer air. As a result, heating energy is minimized.

As with the single-fan dual-duct system, a pair of ducts delivers heated and cooled air to VAV mixing boxes in each zone. Each box modulates the flow of hot and cold air to its zone to maintain space temperature setpoint. The system will usually have an economizer on the cold deck; the hot deck may take air only from the return. Return/exhaust fans may also be incorporated.

The hot and cold decks may either be completely built-up, consist of air handlers with water coils, or be separate packaged units. For example, the hot deck may be a packaged rooftop gas furnace, and the cold deck may be a packaged rooftop DX unit.

Most of the requirements for the dual-fan dual-duct system are the same as for the single-fan dual-duct system. The following are the differences:

1. For dual fan systems, supply air flow includes the design cold deck supply, and the hot deck supply at the time of the cooling peak. Fan power is based on the design cold deck horsepower, and the hot deck fan power at the time of the cooling peak. Since the hot deck fan will normally be operating at a reduced air flow at the time of the cooling peak (or off), the hot deck fan horsepower may be determined on this basis. If unknown, the designer may assume that both hot deck airflow and power is 35 percent of design.
2. **Ventilation** may be delivered through the hot deck, the cold deck or both. If all ventilation air is provided through the cold deck, and the

hot deck draws air only from the return, then the minimum cold duct cfm of the zone VAV box may be set to the required outdoor ventilation rate; the hot duct damper can close fully.

3. A fully integrated **economizer** with compliant high limit switch controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling [P]. This economizer may be on the cold deck only.

Example 4-40– Dual-Fan Dual-Duct Fan Power

Question

How is the fan power calculated for a dual-fan dual-duct VAV system having a 24,000 cfm, 25 BHP cold deck fan, and a 10,000 cfm, 9 BHP hot deck fan? Load calculations show that the hot deck will deliver 25 percent airflow at the time of the cooling peak. Both fans are modulated with variable frequency drives having efficiencies of 96 percent.

Answer

Assuming the belt drive efficiencies are 97 percent, and motor efficiencies are from Table B-8, the cold deck power is:

(25 BHP x 0.746kW/HP) / (0.88 x 0.97 x 0.96) = 22.8 kW

For the hot deck, assume that fan power will drop as the square of the airflow (the fan laws say the cube, but this is unrealistic). Power consumption at 25 percent airflow is then:

(9BHP x 0.746kW/HP) / (0.85 x 0.97 x 0.96) = 8.5 kW

8.5 kW x (2500cfm/10,000cfm)2 = 4.35 kW

Total power is:

22.8 kW + 4.3 kW = 27.0 kW

and total airflow is :

24,000 cfm + 2500 cfm = 26,500 cfm

so that system fan power index is

(27.0 kW x 1000 W/kW) / 26,500 cfm = 1.0 W/cfm

4. **VAV Zone Controls** shall be in accordance with Section 4.2.1F and 4.2.1G [M] and Section 4.2.2[P].

F. Packaged Terminal Air Conditioner with Gas-Furnace or Heat Pump

Packaged terminal air conditioners (PTAC) are units designed to supply heating and cooling to an individual space. They are usually smaller in capacity than packaged rooftop units, and are designed for through-the-wall installation. All PTAC units discharge air directly into the space without duct work. Cooling is provided by a compressor with direct expansion coil. Heating is provided by either using the compressor in a heat pump cycle or by a gas furnace. Units with electric resistance heating are also available, but their use is severely restricted by the *Standards*.

A PTAC unit is usually controlled directly by a thermostat that cycles the compressor on and off. This thermostat may be either integral to the unit or wall-mounted.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B above and **equipment sizing** must be in accordance with Section 4.2.2A[P]. Allowable safety factors and pick-up factors may be applied.
2. Any **equipment** listed in Appendix B, Table B-9, shall comply with the listed efficiencies [M].
3. **Fan power consumption** is not regulated explicitly, as the requirements apply only to systems having fans 25 horsepower and larger.
4. **Ventilation** shall be in accordance with Section 4.2.1C - 4.2.1F [M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Conference rooms, or other spaces having dense but intermittent occupancy levels, may require transfer fans or other mechanisms to accommodate their increased ventilation requirements.
5. An **economizer** is not required for PTAC units under 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F above) [P]. Economizers are also not required for units serving residential living quarters and hotel/motel guest rooms.
6. With the exception of supplementary resistance heating as described below, **electric-resistance heating** (Section 4.2.2H) is permitted only where [P]:
   a. The total capacity of all electric resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building; or

b. The total capacity of all electric resistance heating systems serving the building, excluding supplementary resistance heaters in heat pumps, is less than 3 kW.

In practical terms, these exceptions allow a building with a single small PTAC to use resistance heat instead of a heat pump. A large building may have a few PTACs with electric heat, provided that 90 percent of the building's heating capacity is provided by other types of units. Any other building heated and cooled by PTACs must use heat pump PTACs.

When a PTAC is specified with supplementary resistance heaters, the heat pump compressor capacity must be at least 75 percent of the design heating load at design conditions per Section 4.2.2H[P].

7. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and 4.2.2D[[P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   If the PTAC unit is serving a **hotel/motel guest room**, the thermostat must have numeric temperature setpoints in °F and stop points accessible only to authorized personnel [M].

   Ventilation air must be provided at least 55 out of every 60 minutes (4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to On.

8. **System controls** shall be in accordance with Section 4.2.1H[M], and 4.2.2D[P]. The requirements are as follows:

   A **certified automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation. Systems serving hotel/motel guest rooms are exempt provided they have a readily accessible manual shut-off switch

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three air changes in not more than one hour, whichever is less. Systems serving hotel/motel guest rooms are exempt.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints (Section 4.2.1H)[M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F, or for hotel/motel guest rooms.

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down. Dampers are not required in hotel/motel guest rooms or other applications where exhaust fans run continuously.

   When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since PTAC units serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.

9. **Heat pump thermostats and controls** must meet all of the requirements in items 7 and 8 above, and in addition must have controls [M]:

a. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and

b. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

The controls may allow supplementary heating during:

a. Defrost; and

b. Transient periods such as start-up or raising the room thermostat setpoint if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

G. Four-Pipe Fan Coil System with Central Plant

A four pipe fan coil (FPFC) is a small unit consisting of a fan, separate heating and cooling coils, a replaceable filter and a drain pan for condensate. FPFCs are available in various configurations to fit under windowsills, above furred ceilings and in vertical spaces within walls. Ventilation air can be provided through the wall or via a central ventilating system.

A central plant, consisting of a hot water boiler and chiller, provides heating and cooling to the fan coil units.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2Band **equipment sizing** must be in accordance with Section 4.2.2A[P]. Allowable safety factors and pick-up factors may be applied.

2. Any **equipment** listed in Appendix B, Table B-9, shall comply with the listed efficiencies [M]. Centrifugal chillers designed to operate at other than ARI conditions need to comply with the trade-off Tables 1-C8, 1-C9 and 1-C10.

3. **Fan power consumption** is not regulated explicitly, as the requirements apply only to systems having fans 25 horsepower and larger.

4. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A) [P].

5. Ventilation shall be in accordance with Section 4.2.1D- G [M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Ventilation in through-the-wall units may be directly from the outdoors, although wind pressure may cause problems in this arrangement.

   When ventilation is via a central fan system, the duct work must deliver the required amount of air directly to each space. If the FPFC units are above the ceiling in a return plenum, then the ventilation air supply must be either directly connected to the unit or ducted to discharge either:

   a. Within 5 feet of the unit; or

   b. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute (Section 4.2.1F).

6. An **economizer** is not required for FPFC units under 2,500 cfm supply air and 75,000 Btu/hr cooling [P]. Economizers are also not required for units serving residential living quarters and hotel/motel guest rooms.

   Water-side economizers should be evaluated for buildings in favorable climates.

7. **Electric resistance heating** for local heating, etc. is prohibited in most circumstances [P]. The designer should refer to Section 4.2.2H for the exceptions.

8. **Zone Controls** shall be in accordance with Section 4.2.2H [M] and 4.2.2D above[P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (4.2.1G above) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to **On**. This is not required if a central system is used to deliver ventilation air independent of unit fan operation.

9. **System controls** shall be in accordance with Section 4.2.1G above and H[M], and 4.2.2D above and E. [P]. The requirements are as follows:

   An **automatic time switch** with weekday/ weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G above. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three air changes per hour, whichever is less. If a central ventilation system is used to supply ventilation air directly to the space, then unit fans do not need to be started ahead of time.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down. Dampers are not required in hotel/motel guest rooms or other applications where exhaust fans will operate continuously.

   When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since FPFC units serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.

10. Cooling tower fans over 5 hp must have two-speed, pony motors or variable speed drives [P].

11. **Ducts, if any,** must be installed, sealed and insulated per Section 4.2.1J above [M]. Ducts must be insulated in compliance with §124 of the *Standards* or Section 4.2.1J above [M].

12. **Piping** for unit hot and chilled water coils must be insulated in accordance with Section 4.1.2I above[M].

H. Water Loop Heat Pump System with Central Plant

Water loop heat pumps (WLHP) provide heating and cooling for a number of individually controlled zones by operation of water-to-air heat pump units located in each space. Each heat pump is piped to a common circulation loop and will take heat from, or reject heat to the loop, depending on whether the unit is in the heating or cooling mode.

During some periods, the thermal requirements of units in the heating mode will balance with the units in the cooling mode, and the loop will remain at a constant temperature. At other times the loop will be out of balance, and heat must be made up by a boiler or rejected by a cooling tower.

WLHPs are available in various sizes and configurations to fit under windowsills, above furred ceilings, stacked in vertical spaces within walls, in mechanical rooms, and on rooftops. Small units are often used for each exterior space, with larger units serving the interior.

Ventilation air can be provided through the wall in perimeter units, or via a central ventilating system.

A central plant, consisting of a hot water boiler and cooling tower, provides supplemental heating and heat rejection for the loop.

The requirements for this system are as follows:

1. **Load calculations** must be in accordance with Section 4.2.2B, and **equipment sizing** must be in accordance with Section 4.2.2A [P]. Allowable safety factors and pick-up factors may be applied.
2. Any **equipment** listed in Appendix B, Table B-9, of Appendix B shall comply with the listed efficiencies [M]**.**
3. **Fan power consumption** must be no more than 0.8 Watts/cfm of supply air for constant volume systems, in accordance with Section 4.2.2C [P]. The limit applies to the sum of the horsepower of all supply, return, and exhaust fans in the space-conditioning system that operates during the peak design period. Space exhaust fans such as toilet exhausts are included, while economizer fans that do not operate at peak are excluded.

   The limit does not apply to any system having fans totaling less than 25 HP. Because most WLHP systems are relatively small, fan horsepower will not usually be a consideration.
4. **Pumps** are not specifically addressed by the *Standards*, except that the same sizing restrictions apply to pumps as to the rest of the heating and cooling system components (Section 4.2.2A).
5. **Ventilation** shall be in accordance with Section 4.2.1C [M]. For most office spaces, a minimum of 0.15 cfm/ft² or 15 cfm/person, whichever is greater, shall apply. Areas with unusual sources of contaminants may have additional requirements. Natural ventilation may be used in place of mechanical ventilation in spaces having sufficient access to the outdoors through operable windows.

   Ventilation in through-the-wall units may be directly from the outdoors, although wind pressure may cause problems in this arrangement.

   When ventilation is via a central fan system, the duct work must deliver the required amount of air directly to each space. If the WLHP units are above the ceiling in a return plenum, then the ventilation air supply must be either directly connected to the unit or ducted to discharge either:

   a. Within five feet of the unit; or

   b. Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute (Section 4.2.1F).

6. A fully integrated **economizer** with controls must be provided for each system delivering over 2,500 cfm supply air and 75,000 Btu/hr cooling (Section 4.2.2F)[P]. A water economizer must meet 100 percent of the expected system cooling load as calculated at outside air temperatures of 50°F dry-bulb and 45°F wet-bulb and below.
7. **Electric resistance heating** for local heating, etc. is prohibited in most circumstances [P]. The designer should refer to Section 4.2.2H for the exceptions.

   Electric boilers for supplemental loop heating are not allowed unless it can be demonstrated to the satisfaction of the enforcement agency that at least 60 percent of the annual heating energy requirement is supplied by site solar or recovered energy.
8. **Zone Controls** shall be in accordance with Section 4.2.1H [M] and 4.2.2D [P].

   A **thermostat** must be provided to control heating and cooling to each zone [M]. The heating setpoint must be adjustable down to 55°F or lower, and the cooling setpoint up to 85°F or higher. There must be at least a 5°F deadband between heating and cooling setpoints, or the thermostat must be manually switched between heating and cooling.

   Ventilation air must be provided at least 55 out of every 60 minutes (Section 4.2.1G) [M]. When outdoor air ventilation is provided mechanically, the **Auto/On** fan switch, if any, should be set to **On**. This is not required if a central system is used to deliver ventilation air independently of unit fan operation.
9. **System controls** shall be in accordance with Section 4.2.1G and 4.2.1H [M], and 4.2.2D[P]. The requirements are as follows:

   An **automatic time switch** with weekday/weekend features shall start and stop the equipment [M]. A four-hour manual override must be accessible to the occupants for off-hours operation.

   The controls must start the system sufficiently ahead of occupancy and operate the system to accomplish a **building purge** in accordance with Section 4.2.1G. For office buildings, the purge requirement is one hour at the minimum ventilation rate, or three complete air changes, whichever is less. If a central ventilation system is used to supply ventilation air directly to the space, then unit fans do not need to be started ahead of time.

   The controls must restart the system during unoccupied times to maintain **heating setback/cooling setup** setpoints (Section 4.2.1H) [M]. Heating setback control is not required where winter design temperatures are above 32°F; cooling setup control is not required where summer design temperatures do not exceed 100°F.

   Outdoor air supply and exhaust equipment shall have **dampers** that automatically close during periods the equipment is shut down.

   When a system serves more than 25,000 square feet, **isolation devices** must be incorporated so that areas of no more than 25,000 square feet can be shut down independently of each other [M]. Since WLHP units normally serve areas smaller than this, isolation is accomplished by using separate automatic time switches for each unit or group of units.
10. 11. Cooling tower fans over 5 hp must have two-speed, pony motors or variable speed drives [P].
11. **Ducts, if any** must be installed, sealed and insulated per Section 4.2.1J[M].
12. **Piping** must be insulated in accordance with Section 4.2.1I[M]. Note that piping for WLHPs will not normally need to be insulated.

4.3 Mechanical Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the forms and recommended procedures documenting compliance with the mechanical requirements of the *Standards*. It does not describe the details of the requirements; these are presented in Section 4.2. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the building department plan checkers who are examining those documents for compliance with the *Standards*.

The use of each form is briefly described below, then complete instructions for each form are presented in the following subsections. The information and format of these forms may be included in the equipment schedule.

MECH-1: Certificate of Compliance
This form is required for every job, and it is required to appear *on the plans*.

MECH-2: Mechanical Equipment Summary
This form summarizes the major components of the heating and cooling systems, and documents compliance with the minimum efficiency, economizer and VAV airflow requirements.

MECH-3: Mechanical Ventilation
This form documents the calculations used as the basis for the outdoor air ventilation rates. For VAV systems, it is also used to show compliance with the reduced airflow rates necessary before reheating, recooling or mixing of conditioned airstreams.

MECH-4: Mechanical Sizing and Fan Power
This form is used to list the size of all equipment regulated by these *Standards*, and to document compliance with the fan power limitations.

MECH-5: Mechanical Distribution Summary (Performance Use Only)
This form is used (under the performance approach only) to verify duct tightness by the installer and/or HERS rater (third-party). Compliance credit requires third-party field verification.

4.3.1 MECH-1: Certificate of Compliance

MECH-1 is the primary mechanical form. Its purpose is to provide compliance information in a form useful to the enforcement agency's field inspectors.

This form should be included on the plans, usually near the front of the mechanical drawings. A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the *Energy Commission's* forms), provided the information is the same and in similar format. Additionally, if none of the information requested for Part 2 of 2 of this form applies to the job, the building department does not have to require that these parts be included on the plans.

A. MECH-1 Part 1 of 2

Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.
2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.

3. **PROJECT ADDRESS** is the address of the project as shown on the plans and known to the building department.

4. **PRINCIPAL DESIGNER - MECHANICAL** is the person responsible for the preparation of the mechanical plans, and the person who signs the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.

5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation. This may or may not be the principal designer (it may be a person specializing in *Standards* compliance work). The person's telephone number is given to facilitate response to any questions that arise.

6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

B. General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to re-submit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.

2. **BUILDING CONDITIONED FLOOR AREA** has specific meaning under the *Standards*. See Section 2.2.1 for a discussion of this definition. The number entered here should match the floor area entered on form ENV-1in Section 3.3.1A.

3. **CLIMATE ZONE** Indicate the climate zone number of the building project

4. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the *Nonresidential Standards* are designated "Nonresidential" here. It is possible for a building to include more than one building type. See Section 2.2.1A for the formal definitions of these occupancies.

5. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2 for detailed discussion of the various choices.

   a. **NEW CONSTRUCTION** should be checked for all new buildings (see Section 2.2.2F), newly conditioned space (see Section 2.2.2B) or for new construction in existing buildings (tenant improvements, see Section 2.2.2C), which are submitted for envelope compliance.

   b. **ADDITION** should be checked for an addition which is not treated as a stand-alone building, but which uses Option 2 described in Section 2.2.2E.

   c. **ALTERATION** should be checked for alterations to existing building mechanical systems (see Section 2.2.2D).

6. **METHOD OF MECHANICAL COMPLIANCE** indicates which method is being used and documented with this submittal:

   a. **PRESCRIPTIVE** should be checked if the mechanical systems comply using only the Mandatory and Prescriptive measures.

   b. **PERFORMANCE** should be checked when the Performance method is used to show compliance. All required Performance documentation must be included in the plan check submittal when this method is used.

7. **PROOF OF ENVELOPE COMPLIANCE** indicates how the envelope has been shown to comply. The envelope must comply before a permit to install a mechanical system is granted:

   a. **PREVIOUS ENVELOPE PERMIT** indicates that the envelope has already been shown to comply. If so, the building department will have the envelope forms on file. This method is typically used for alterations to existing space.

b. **ENVELOPE COMPLIANCE ATTACHED** - is typically used for new buildings.

C. Statement of Compliance

The Statement of Compliance is signed by both the Documentation Author (described above in 4.3.1A aboveand the person responsible for preparation of the plans for the building). This latter person is also responsible for the energy compliance documentation, even if the actual work is delegated to a different person acting as Documentation Author. It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the *Business and Professions Code*, referenced on the Certificate of Compliance, are provided below:

5537. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. *This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.*

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. *This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:*

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. *(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:*

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. *A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.*

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform.

Nothing in this section is intended to imply that a licensed contractor may design work, which is to be installed by another person

D. Mechanical Mandatory Measures

The Mandatory Measures must be incorporated into the construction documents. The designer may use whatever format is most appropriate for specifying the mandatory measures in the plan set. In general, this will take the form of a note block near the front of the set, possibly with cross-references to other locations in the plans where measures are specified. This space should be used to indicate the sheet number(s) on the plans where these notes can be found.

A sample, generic mechanical mandatory measures note block is shown in Example 4-41. This particular format allows the designer to check the appropriate boxes to indicate the applicable mandatory measures.

Example 4-41– Sample Notes - Mechanical Mandatory Measures

Equipment and Systems Efficiency

Any appliance for which there is a California standard established in the Appliance Efficiency Standards may be installed only if the manufacturer has certified to the *Energy Commission*, as specified in those regulations, which the appliance complies with the applicable standard for that appliance. Included are room air conditioners, central air conditioning heat pumps (regardless of capacity, except that requirements for central air conditioning heat pumps with cooling capacity of 135,000 Btu/hr or more apply to heating performance but not cooling performance), other central air conditioners with a cooling capacity less than 135,000 Btu/hr, fan type central furnaces with input rate less than 400,000 Btu/hr, boilers wall furnaces, floor furnaces, room heaters, unit heaters and duct furnaces shall have been certified to the *Energy Commission* by its manufacturer to comply with the Appliance Efficiency Standards.

The following space-conditioning equipment may be installed only if the manufacturer has certified that the equipment meets or exceeds all applicable efficiency requirements listed in §112 of the *Standards*: all air conditioners, heat pumps and condensing units >135,000 Btu/hr; all water chillers; all gas-fired boilers >300,000 Btu/hr; all oil-fired boilers >225,000 Btu/hr; and all warm air furnaces and combination warm air furnaces/air-conditioning units >225,000 Btu/hr. Fan type central furnaces shall not have a pilot light.

Piping, except those conveying fluids at temperatures between 60°F and 105°F, or within HVAC equipment, shall be insulated and protected from damage in accordance with *Standards* §123.

Air handling duct systems shall be constructed, installed, sealed, insulated and protected from damage as provided in Chapter 6 of the California Mechanical Code (refer to §124).

Controls

Each space-conditioning system serving building types such as offices and manufacturing facilities (and all others not explicitly exempt from the requirements of §122(e)) shall be installed with an automatic time switch with an accessible manual override that allows operation of the system during off-hours for up to four hours. The time switch shall be capable of programming different schedules for weekdays and weekends; and has program backup capabilities that prevent the loss of the device’s program and time setting for at least 10 hours if power is interrupted.

Each space-conditioning system shall be installed with an occupancy sensor to control the operating period of the system.

Each space-conditioning system shall be installed with a four-hour timer that can be manually operated to control the operating period of the system.

Each space-conditioning system shall be installed with controls that temporarily restart and temporarily operate the system as required to maintain a setback heating thermostat setpoint.

Each space-conditioning system shall be installed with controls that temporarily restart and temporarily operate the system as required to maintain a setup cooling thermostat setpoint.

Each space-conditioning system serving multiple zones with a combined conditioned floor area more than 25,000 square feet shall be provided with isolation zones. Each zone shall:

> not exceed 25,000 square feet; shall be provided with isolation devices, such as valves or dampers, that allow the supply of heating or cooling to be
>
> setback or shut off independently of other isolation areas; and shall be controlled by a time control device as described above.

Each space-conditioning zone shall be controlled by an individual thermostatic control that responds to temperature within the zone. Where used to control heating, the control shall be adjustable down to 55°F or lower. For cooling, the control shall be adjustable up to 85°F or higher. Where used to control both heating and cooling, the control shall be capable of providing a dead band of at least 5°F within which the supply of heating and cooling is shut off or reduced to a minimum.

Thermostats shall have numeric setpoints in °F.

Thermostats shall have adjustable setpoint stops accessible only to authorized personnel.

Heat Pumps shall be installed with controls to prevent electric resistance supplementary heater operation when the heating load can be met by the heat pump alone. Electric resistance supplementary heater operation is permitted during transient periods, such as start-ups and following room thermostat setpoint advance, when controls are provided which use preferential rate control, intelligent recovery, staging, ramping, or similar control mechanisms designed to preclude the unnecessary operation of supplementary heating during the recovery period. Supplementary heater operation is also permitted during defrost.

Example 4-42– Sample Notes (cont'd)

Ventilation

Controls shall be provided to allow outside air dampers or devices to be operated at the ventilation rates as specified in these plans.

Gravity or automatic dampers interlocked and closed on fan shutdown shall be provided on the outside air intakes and discharges of all space-conditioning and exhaust systems.

All gravity ventilating systems shall be provided with automatic or readily accessible manually operated dampers in all openings to the outside, except for combustion air openings.

Completion and Balancing

All ventilation systems shall be documented per California Safety Code (Title 8, Section 5142(b)) to be providing the minimum required ventilation rate as determined using one of the following procedures:

(1) Air Balancing: all space-conditioning and ventilation systems shall be balanced to the quantities specified in these plans, in accordance with the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983), or Associated Air Balance Council (AABC) National Standards (1989).

(2) Outside Air Certification: The system shall provide the minimum outside air as shown on the mechanical drawings, and shall be measured and certified by the installing licensed C-20 mechanical contractor.

(3) Outside Air Measurement: The system shall be equipped with a calibrated local or remote device capable of measuring the quantity of outside air on a continuous basis and displaying that quantity on a readily accessible display device.

Another method approved by the *Energy Commission*.

Service Water Heating Systems

The following service water heating systems and equipment may be installed only if the manufacturer has certified that the equipment meets or exceeds all applicable efficiency requirements listed in the *Appliance Efficiency Regulations* or Appendix B, Table B-9.

Unfired service water heater storage tanks and backup tanks for solar water heating systems shall have either:

external insulation with an installed R-value of at least R-12; internal and external insulation with a combined R-value of at least R-16; or

sufficient insulation so that the heat loss of the tank surface based on an 80°F water-air temperature difference shall be less than 6.5 Btu/hr/ft² .

If a circulating hot water system is installed, it shall have a control capable of automatically turning off the circulating pump(s) when hot water is not required.

Lavatories in restrooms of public facilities shall be equipped with either:

Outlet devices that limit the flow of hot water to a maximum of 0.5 gallons per minute

Foot actuated control valves, and outlet devices that limit the flow of hot water to a maximum of 0.75 gallons per minute.

Proximity sensor actuated control valves, and outlet devices that limit the flow of hot water to a maximum of 0.75 gallons per minute.

Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.25 gallons/cycle (circulating system).

Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.50 gallons/cycle (non-circulating system).

Self-closing valves, and outlet devices that limit the flow of hot water to a maximum of 2.5 gallons per minute, and 0.75 gallons/cycle (foot switches and proximity sensor controls).

Lavatories in restroom of public facilities shall be equipped with controls to limit the outlet temperature to 110°F.

Pools and Spas

Pool and/or spa heating systems or equipment shall be installed only if the manufacturer has certified that the system or equipment meets the requirements of §s 114 and 115 of the Standards. Equipment shall not have a pilot light. All such systems shall be installed with at least 36 inches of pipe between the filter and the heater to allow for the future addition of solar heating equipment.

A cover shall be provided for outdoor pools.

A cover shall be provided for outdoor spas.

Pools shall be installed with directional inlets that adequately mix the pool water.

Pool circulation pump(s) shall be provided with a time switch that allows the pump to be set to run in the off-peak electrical demand period, and for the minimum time necessary to maintain the water in the conditions required by applicable public health standards.

To verify certification, use one of the following options:

1. The Energy Hotline can verify certification of appliances not found in the above directories.
2. The *Energy Commission 's* Web Site includes listings of energy efficient appliances for several appliance types. The web site address is www.energy.ca.gov/efficiency/appliances.
3. The complete appliance databases can be downloaded from the *Energy Commission 's* Internet at www.energy.ca.gov/efficiency/appliances. This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress these files. Then download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated.
4. The Air Conditioning and Refrigeration Institute (ARI) Directory of Certified Unitary Products and Directory of Certified Applied Air-Conditioning Products can be used to verify certification of air-conditioning equipment.

E. MECH-1 Part 2 of 2

System Features

This section is used to identify the mandatory and prescriptive features that will be verified by the field inspector. The form has columns for up to 3 systems. Additional forms should be attached for additional systems. When systems are identical, a single column may be used, and all systems listed in the **SYSTEM NAME** field. A **CODE TABLE** found toward the bottom of the form lists the acceptable entries. Either the abbreviation or the full entry is acceptable. Fields that are not applicable may be left blank or designated “N/A”.

1. **SYSTEM NAME** is the name of the system as shown on the plans.
2. **TIME CONTROL** indicates the type of time control device for this system:

   S Programmable time switch with weekday/weekend features.

   O Occupancy sensor, for intermittently occupied spaces only

   M Manual timer, for intermittently occupied spaces only
3. **SETBACK CONTROL** indicates whether controls which can restart the equipment based on space temperature during off-hours are required:

   H Heating: Required if design heating temperature is less than 32°F

   C Cooling: Required if design cooling temperature is greater than 100°F

   B Both
4. **ISOLATION ZONES** indicates the number of isolation zones that are required when the area served by a single HVAC system exceeds 25,000 square feet.

5. **HEAT PUMP THERMOSTAT** indicates that the system incorporates a heat pump which will be directly controlled by a heat pump thermostat which minimizes the use of electric resistance heat.
6. **ELECTRIC HEAT** indicates whether any electric heat is approved for this system. The capacity in kW and the location (system, room number, etc.) should be indicated in the field notes.
7. **FAN CONTROL** indicates the type of modulation the supply and return fans will have in a variable air volume system. For fan systems over 25 hp, the modulation must achieve at least a 50 percent power reduction at 70 percent airflow. The choices are:

   C for a fan that rides the curve. This is suitable only for forward-curved fans.

   I for inlet vanes. Normally, this is suitable only for forward-curved fans. If used with airfoil/backward inclined fans, manufacturer's data showing a 70 percent power reduction at 50 percent airflow must be attached to the form.

   P for variable pitch vanes.

   V for variable frequency drive or variable-speed drive.

   O for other. Manufacturer's data showing a 70 percent power reduction at 50 percent airflow must be attached to the form.

8. **VAV MIN POSITION CONTROL** is used for variable air volume systems only, and indicates that the plans must include a schedule of VAV boxes showing the minimum required airflow to each space.
9. **SIMULTANEOUS HEAT/COOL** indicates that a constant-volume type system will be using simultaneous heating and cooling in order to serve a space with special requirements (humidity control, constant ventilation, etc.)

   If the system serves more than one space, the field notes should indicate the spaces in which this is allowed.

10. **HEAT AND COOL SUPPLY RESET** is required for systems which reheat, recool, or mix conditioned air streams, and indicates that a supply air temperature reset must be incorporated into the control sequences.
11. **HEAT REJECTION CONTROL**
12. **VENTILATION** indicates the manner in which compliance with the ventilation requirements will be achieved:

   B **Air Balance**: Indicates that an air balance will be made by a certified air balance contractor. The inspector should ask to see a copy of the balance report.

   C **Outside Air Certification**: Indicates that the installing licensed C-20 mechanical contractor will measure the outdoor airflow and adjust the system and controls so that the minimum required outdoor ventilation rate is delivered under all operating conditions. A statement indicating that the system provides the minimum outside air as shown on the mechanical drawings must be signed by either the design mechanical engineer, the installing licensed C-20 contractor, or the person with overall responsibility for the design of the ventilation system. The certificate must be presented to the inspector before an occupancy permit is granted.

   M **Measurement**: The system will be equipped with a calibrated device capable of measuring the quantity of outside air and displaying the value.

   D **Demand Control**: The system will be equipped with a demand control ventilation device, which will be installed and adjusted to control carbon dioxide (CO_2) levels.

N **Natural Ventilation**: Operable openings will provide natural ventilation.

13. **OUTDOOR DAMPER CONTROL** indicates the type of controls used to close system intake and exhaust dampers during off hours:

    A **Automatic** motorized damper controls

    G **Gravity** type backdraft dampers

14. **ECONOMIZER TYPE** is used to indicate whether a space-conditioning system has an economizer, and the type. The choices are Air / Water / Not Required / Economizer Control (see §144(e)3).

15. **DESIGN O.A. AIR CFM** indicates the minimum airflow that the space-conditioning system must continuously provide during all occupied hours (from MECH-3, Column H).

16. **HEATING EQUIPMENT TYPE** identifies the type of heating equipment that the field inspector will check for this system. Generic entries such as Boiler or Gas Furnace are acceptable. See Appendix B, Table B-9

    a. **HIGH EFFICIENCY** indicates that the equipment installed has an efficiency higher than required by the *Standards*, and that this higher efficiency was used in the Performance Method to demonstrate compliance with the *Standards*.

       This box should also be checked when higher efficiency equipment is installed as part of a utility rebate program.

    b. **IF YES ENTER EFF. #** if the **HIGH EFFICIENCY** box is checked enter the equipment efficiency and unit here (i.e. AFUE, Thermal EFF, COP).

    c. **MAKE AND MODEL NUMBER** is for the heating equipment identified on the previous line. This entry should match the entry listed on the MECH-2 form.

       It is recognized that the actual make and model of equipment installed is often different from that specified. If so, and if **HIGH EFFICIENCY** is indicated, the substitute equipment must be at least as efficient as the equipment originally specified. Enter the equipment efficiency and unit here (i.e. AFUE, Thermal EFF, COP).

       Manufacturer's Performance data for substitute equipment must be resubmitted to the building department for approval. Upon reapproval, the building department should make notes to that effect in the **NOTE TO FIELD** column.

17. **COOLING EQUIPMENT TYPE** is identical to HEATING EQUIPMENT TYPE described above. Note that, when substitute HIGH EFFICIENCY equipment is used, the equipment must satisfy all specified efficiency indicators, including SEER, EER, IPLV, etc. See Appendix B, Table B-9

18. **PIPE INSULATION REQUIRED** should list the function of the pipe when pipe insulation is required. Appropriate entries might be supply, return, nonrecirculating or recirculating (for service water), chilled supply, etc.

19. **PIPE/DUCT INSULATION PROTECTED?** Pipe/Duct insulation shall be protected from damage, including that due to sunnlight, moisture maintenance and wind. See §123 and 124.

20. **HEATING DUCT LOCATION** indicates the location of the duct work for the purposes of establishing the ambient temperature. Most common locations include:

    a. **Conditioned** - for duct work located directly within the conditioned space.

    b. **Plenum** - for duct work located above a ceiling, but below an insulated roof

c. **Attic** - for duct work located above an insulated ceiling, and below an uninsulated roof.

d. **Unconditioned** - for duct work running through spaces that are not conditioned.

e. **Roof** - for duct work exposed on a roof.

21. **DUCT R-VALUE** is the required R-value of the duct insulation, based on duct location and climate. If the designer has specified a higher R-value, the higher value should be entered instead.

22. **COOLING DUCT LOCATION/DUCT R-VALUE** is identical to HEATING DUCT LOCATION and DUCT R-VALUE.

23. **VERIFIED SEALED DUCTS IN CEILING/ROOF SPACE**

F. Notes To Field

This column is for building department use. It is intended as a communication mechanism between the plan checker and field inspector. The plan checker should note any critical or unusual details that are important to the building's energy compliance.

4.3.2 MECH-2: Mechanical Equipment Summary

This form is used to summarize all space-conditioning equipment whose efficiency is regulated by either these *Standards* or the *Appliance Efficiency Standards*. Only equipment subject to these regulations should be listed; air handlers, pumps, cooling towers and other unregulated equipment should not be listed. As many copies of this form should be used as are needed to list all equipment.

Note that, while air handlers are not listed on this form, their airflow and fan power consumption must be included on MECH-4.

The designer may elect to include the information on this form as part of Equipment Schedules on the drawings. If so, then this form may be left blank, except for a note identifying the drawing page(s) where this information may be found.

A. MECH-2 Part 1 of 2

Chiller and Tower Summary

1. **EQUIPMENT NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **EQUIPMENT TYPE** lists the type of chiller. Chiller types include centrifugal or reciprocating.

   a. Centrifugal: Compression refrigeration system using rotary centrifugal compressor.

   b. Reciprocating. Compression refrigeration system using reciprocating positive displacement compressor.

3. **QTY.** is the number of each unique equipment type.

4. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

5. **TONS** is the equipment capacity (12,000 Btu/h is equivalent to 1 ton).

6. **PUMPS**

   a. **TOT. QTY** is the number of pumps.

   b. **GPM** is the flow rate in gallons per minute.

   c. **BHP** is the pump brake horsepower.

d. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

e. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

f. **PUMP CONTROL** is the control type, which is either variable flow, riding curve or two speed/stages).

B. DHW/Boiler Summary

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.
2. **SYSTEM TYPE** includes:
   a. Boilers: electric, fossil fuel, natural draft, forced/induced draft or hot water.
   b. Water Heaters: electric or gas.
3. **DISTRIBUTION TYPE** is standard or recirculating.
4. **QTY.** is the number of individual boilers or tanks in the system.
5. **RATED INPUT** is the rated input capacity listed in certification information for the water heater (in Btu/hr).
6. **VOL. (GALS.)** is volume in gallons of the water heater or storage tank.
7. **ENERGY FACTOR OR RECOVERY EFFICIENCY** is the efficiency of the water heater tank. If water heating is provided by a boiler, the efficiency (thermal efficiency) must include the effects of the storage tank. All efficiencies shall be in accordance with Table B-9 in Appendix B
8. **STANDBY LOSS OR PILOT ENERGY** is standby loss for large (greater than 75,000 Btu/hr) or pilot energy (in Btu/hr) for instantaneous water heaters and large storage (boiler) gas heater type. Enter 0 for no pilot, or 800 if pilot exists.
9. **TANK INSUL.** is the external R-value of insulation on an unfired storage tank Or fired storage tank.

C. Central System Ratings

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.
2. **SYSTEM TYPE** is furnace, heat pump, hydronic or Direct expansion (DX) compressors.
3. **QUANTITY** is the number of unique system types.
4. **HEATING**
   a. **OUTPUT** is the heating capacity in Btu/hr at the design conditions. When using the Prescriptive Approach, this number must not exceed the maximum adjusted load (last line of **2. Sizing**) as calculated on MECH-4, unless an exception was taken on that form. It should also be consistent with the total capacity as indicated on MECH-4.
   b. **AUX. kW** is any auxiliary or supplemental electric heating (in kW) which is typically installed in a Heat Pump system.
   c. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

5. **COOLING**

   a. **OUTPUT** is the cooling capacity in Btu/hr at the design conditions. When using the Prescriptive Approach, this number must not exceed the maximum adjusted load (last line of **2. Sizing**) as calculated on MECH-4, unless an exception was taken on that form. It should also be consistent with either the sensible or total capacity as indicated on MECH-4.

   b. **SENSIBLE** is sensible cooling capacity at the design conditions, based on equipment manufacturer's ratings.

   c. **EFFICIENCY** is the efficiency at the test conditions as specified in Appendix B, Table B-9, Minimum Mechanical Equipment Efficiencies.

   d. **ECONOMIZER TYPE** is used for space-conditioning equipment to indicate an air or water economizer. An economizer is not required for chillers.

D. Central Fan Summary

1. **SYSTEM NAME** lists the equipment tag or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.

2. **FAN TYPE** list the fan type regardless of horsepower whether constant volume, inlet vane, discharge damper or variable speed. This is used to document compliance with the fan power requirements of §144(c) of the *Standards.*

3. **MOTOR LOCATION** is in airstream or outside airstream.

4. **SUPPLY FAN**

   a. **CFM** is the airflow at the design conditions. When using the Prescriptive Approach, this number must match the cfm listed for the supply fan on form MECH-4,**FAN POWER CONSUMPTION**, Column G.

   b. **BHP** is supply fan brakehorsepower (see Section 4.2.2C). When using the Prescriptive Approach, this number must be listed on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

   c. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

   d. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

5. **RETURN FAN** information includes fan CFM, brakehorsepower, and motor and drive efficiency (see SUPPLY FAN above and Section 4.2.2C).

   a. **CFM** is the airflow at the design conditions.

   b. **BHP** is return fan brake horsepower (see Section 4.2.2C). When using the Prescriptive Approach, this number must be listed on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

   c. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

   d. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

E. MECH-2

Part 2 of 2

VAV Summary

1. **ZONE NAME** lists zone name or other identifiers as shown on the drawings. If more than one zone is identical to other zones all maybe listed within the same zone name, and all may be listed on a single line or more.

2. **VAV**

   a. **SYSTEM TYPE** is CAV, VAV, VAV with series fan or VAV with parallel fan, and is used to specify the type of VAV box, and what type of fan is included.

   b. **QUANTITY** is the total number of identical VAV boxes.

   c. **MINIMUM CFM RATIO** is the minimum design air flow rate, which is used to document compliance with §144(d) of the *Standards*.

   d. **REHEAT COIL**

      TYPE is hot water or electric. Note that when using the Prescriptive Approach, electric reheat is only allowed as listed under §144(g) of the *Standards.*

      DELTA T is the temperature difference at which heat is supplied over coils.

3. **FAN**

   a. **FLOW RATIO** is used to specify the ratio of airflow in a Parallel Fan or Series Fan powered VAV box.

   b. **CFM** is the total airflow at the design conditions for a fan powered VAV box.

   c. **BHP** is supply fan brakehorsepower (see Section 4.2.2C). When using the Prescriptive Approach, this number must be included on form MECH-4,**FAN POWER CONSUMPTION**, Column B.

   d. **MOTOR EFFICIENCY** is from equipment information or from Appendix B, Table B-8.

   e. **DRIVE EFFICIENCY** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

   f. **BASEBOARD TYPE AND OUTPUT** Type is hydronic or electric. Output is in Btuh/sf or kWh for the each zone.

F. Exhaust Fan Summary

1. **ROOM NAME** lists the spaces or other identifier as shown on the drawings. If more than one space-conditioning system is identical, all may be listed on a single line.
2. **QTY** is the total number of identical exhaust fans.
3. **CFM** is the total airflow at the design conditions for an exhaust fan.
4. **BHP** is the exhaust fan brake horsepower (see Section 4.2.2C). When using the Prescriptive Approach, this number must be included on form MECH-4, **FAN POWER CONSUMPTION**, Column B.
5. **MOTOR EFF.** is from equipment information or from Appendix B, Table B-8.
6. **DRIVE EFF.** default values are 1.0 for a direct drive and 0.97 for a belt drive. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

4.3.3 MECH-3: Mechanical Ventilation

This form is used to document the design outdoor ventilation rate for each space, and the total amount of outdoor air that will be provided by the space-conditioning or ventilating system. For VAV systems, this form also documents the reduced cfm to which each VAV box must control before allowing reheat.

One copy of this form should be provided for each mechanical system. Additional copies may be required for systems with a large number of spaces or zones. In lieu of this form, the required outdoor ventilation rates and airflows may be shown on the plans.

Note that, in all of the calculations that compare a supply quantity to the REQ'D O.A. quantity, the actual percentage of outdoor air in the supply is ignored.

The design outdoor ventilation rate and air distribution assumptions made in the design of the ventilating system must be documented on the plans. Documentation must be in accordance with §10-103 of Title 24.

Areas in buildings for which natural ventilation is used should be clearly designated. Specifications must require that building operating instructions include explanations of the natural ventilation system.

A. MECH-3

Ventilation Calculations

1. **COLUMN A - ZONE/SYSTEM** is the system or zone identifier as shown on the plans.
2. **AREA BASIS -** outdoor air calculations are documented in Columns B, C and D. If a space is naturally ventilated, it should be noted here and the rest of the calculations (Columns B-K) skipped.

   a. **COLUMN B - COND. AREA (SF)** is the area in square feet for the SPACE, ZONE, or SYSTEM identified in Column A.

   b. **COLUMN C - CFM PER SF** is the minimum allowed outdoor ventilation rate as specified in Table No. 1-F of the *Standards* for the type of use listed.

   c. **COLUMN D - MIN CFM** is the minimum ventilation rate calculated by multiplying the COND. AREA in Column B by the CFM PER SF in Column C.
3. **OCCUPANCY BASIS** outdoor air calculations are calculated in Columns E, F and G.

   a. **COLUMN E - NO. OF PEOPLE** is determined using one of the methods described in Section 4.2.1F.

   b. **COLUMN F - CFM PER PERSON** is determined using one of the methods described in Section 4.2.1.F.

   c. **COLUMN G - MIN CFM** is the NO. OF PEOPLE multiplied by CFM PER PERSON.
4. **REQ'D O.A.** - **COLUMN H** is the larger of the outdoor ventilation rates calculated on an AREA BASIS or OCCUPANCY BASIS (Column D or G).
5. **DESIGN OUTDOOR AIR CFM -COLUMN I** is the actual outdoor air quantity to be provided based on cooling loads. If this quantity is less than the REQ'D O.A., then TRANSFER AIR (Column K) will have to make up the difference.
6. **VAV MIN. CFM** - **COLUMN J** calculations are made for variable air volume systems only, in Column J. Is the maximum airflow to which the VAV box supply must be reduced before reheat is permitted. It is calculated as the largest of:

   a. design fan supply cfm (MECH-2, Part 2) x 30%; or

   b. condition area (ft^2) x 0.4 cfm/ft^2; or

   c. 300 cfm
7. **TRANSFER AIR** - **COLUMN K** is the amount of air that must be directly transferred from another space so that the space supply is always no less than REQ'D O.A. It is calculated as the largest of:

   a. REQ'D O.A. - DESIGN Outdoor Air (Column H - I); or

   b. REQ'D O.A. - VAV MIN. CFM for a VAV system (Column H - J); or

c. 300 cfm

In these calculations, the actual percentage of outside air in the supply is ignored.

8. **TOTALS** are summed for

   a. **NO. OF PEOPLE** - This value should match the number people used in the load calculations as summarized in the SIZING AND EQUIPMENT SELECTION on MECH-4.

   b. **REQ'D O.A.** - The values listed for the system on MECH-1 Design OUTDOOR AIR CFM be at least this amount. The designer may elect to use a greater amount of outdoor air judged necessary to ensure indoor air quality.

   c. **DESIGN OUTDOOR AIR** - This value should match any amounts listed for cooling equipment sizing on MECH-4 CFM.

4.3.4 MECH-4: Mechanical

A. MECH-4

Sizing and Fan Power

This form is used to document the calculations used in sizing equipment and demonstrating compliance with the fan power requirements when using the Prescriptive Approach. The PROJECT NAME, DATE, SYSTEM NAME and FLOOR AREA served by this system should be entered at the top of the form. One form should be provided for each space-conditioning system.

B. Sizing and Equipment Selection

Separate columns are provided for heating and cooling load documentation. The actual load calculations should not be submitted with this form unless requested by the Building Department.

1. **DESIGN CONDITIONS** documents the outdoor and indoor temperature and humidity conditions used in the load calculations. These temperatures should be taken from ASHRAE publication SPCDX for the building location as described in Section 4.2.2B and found in Appendix C.

   OUTDOOR DRY BULB TEMPERATURE for cooling must be no greater than listed in the Summer Design Dry Bulb 0.5% column. Heating should be no less than the temperature listed in the Winter Median of Extremes.

   OUTDOOR WET BULB TEMPERATURE for cooling must be no greater than the Summer Design Wet Bulb 0.5% column. The heating entry is not used.

   INDOOR DRY BULB TEMPERATURE must be determined in accordance with ANSI/ASHRAE 55-1992, or Chapter 8 of the *ASHRAE Handbook, 1993 Fundamentals Volume*. Winter humidification and summer dehumidification are not required.

2. **SIZING** summarizes the major categories of building loads, as determined by the designer in the load calculations, based on the design conditions.

   a. **DESIGN OUTDOOR AIR** lists the design outdoor quantity determined on form MECH-3, Column I and the corresponding heating and cooling loads. The design outside air load in CFM must be converted to KBtuh in accordance with the procedures described in Chapter 8 of the ASHRAE Handbook, 1993 Fundamentals. The calculations may be done by hand or by a computer program. To make this conversion use the following equation for cooling and heating:

   $DOA_{Kbtuh} = \; T \times DOA_{CFM} \times 1.08$

   Where;

   T = Temperature difference between ambient dry bulb and indoor dry bulb temperature for cooling and heating on MECH-4 in ^{o}F.

DOA = Design Outside Air (From MECH-3, Column I), in Cubic Feet per Minute(CFM)

1.08 Btu-min/hr-ft^3-^oF= Conversion factor from cfm to Btu/hr is equal to 60 minutes per hour times air density 0.075 lb/ft^3 times specific heat of air of 0.24 in Btu/lb-^oF.

b. **ENVELOPE LOAD** summarizes the heat gains and losses through the building envelope, including conduction, solar radiation and infiltration. These loads must be determined using the surface areas and envelope characteristics as documented on form ENV-2, Part 2 of 6, Column E.

The envelope load in KBtuh must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done as follows:

Envelope $Load_{Kbthuh}$ = U (Btu/hr-ft^2-^oF) A (ft^2) X T (^oF)

Where:

U = U-Value of each proposed assembly in Btu/hr-ft^2-^oF.

A = Surface area of each proposed assembly in ft^2

T = Temperature change between dry bulb and indoor dry bulb temperature for cooling and heating on MECH- 4 in ^oF.

c. **LIGHTING** lists the average Watt/ft² power density for the spaces served by this system, as documented on form LTG-2, Adjusted Actual Watts. The calculations may be made by taking. The cooling loads for lighting in kBtuh must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by hand (watts/ft^2x area ft^2 x 0.00341KBtuh) or by a computer program, which uses these procedures. Lighting is disregarded for heating calculations.

PEOPLE lists the number of people as documented on Form MECH-3, and the cooling loads based on the expected activities. The cooling loads for people in KBtuh must be in accordance with the procedures described in Table 3, Chapter 28 of the ASHRAE Handbook, 1997 Fundamentals Volume. The calculations may be done as follows:

$$\text{People Load} = \frac{CFA}{Occ} \times \text{Heat Gain} \times \frac{1}{1000\ ft^2}$$

Where;

People Load = in KBtuh

CFA = Conditioned Floor Area of the permitted building or space in square feet.

Occ = Occupancy load from Mech-3, Column E.

Heat Gain = Includes both Sensible and Latent heat gain from occupant in Btu/hr for each occupancy. See Appendix B, Table 13.

or by a computer program which uses similar procedures. People loads are disregarded for heating calculations.

d. **MISCELLANEOUS EQUIPMENT** lists the average Watts/ft² power density for miscellaneous equipment that contributes to cooling loads. The cooling loads for miscellaneous equipment in KBtuh must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by (watts/ft² x 3.41) or by a computer program. Equipment loads are disregarded for heating calculations.

e. **OTHER** lists any other loads, such as process loads, duct loss and infiltration. The amount should be listed, and the load described. The miscellaneous equipment loads in KBtuh/h must be calculated in accordance with the procedures described in Chapter 26 of the ASHRAE Handbook, 1993 Fundamentals Volume. The calculations may be done by hand or by a computer program, which uses these procedures. This space should also be used for documenting latent loads that are used in selecting the equipment if the selection is based on latent load, rather than sensible load.

f. **OTHER LOADS and SAFETY FACTOR.** The designer is allowed to increase the cooling load by 10 percent and the heating load by 30 percent to account for "Other Loads" such as warm-up and cool-down. The designer is also allowed to increase both heating and cooling loads by an additional 10 percent "Safety Factor" to account for unexpected loads. Therefore, the maximum allowed overall factor is (1.10 1.10) or 1.21 for cooling, and (1.10 1.30) or 1.43 for heating.

g. **MAXIMUM ADJUSTED LOAD** is the cooling and heating loads, adjusted by Other Loads and the Safety Factor. This is usually the sensible load unless latent loads were used in the equipment selection. If latent loads were used, this entry should be the total sensible and latent load.

3. **SELECTION** summarizes how the load calculations are used to select the equipment size:

a. **INSTALLED EQUIPMENT CAPACITY** lists the cooling and heating capacity of the equipment at the design conditions. If the equipment selection is based on sensible load only, the sensible capacity of the equipment is listed here. If equipment selection is based on total load, the total load should be listed here. If the installed capacity is larger than the maximum adjusted load, the designer should explain the exception taken.

C. Fan Power Consumption

This section is used to show how the fans associated with the space-conditioning system comply with the maximum fan power requirements. All supply, return, exhaust fans, and space exhaust fans – such as toilet exhausts – in the space-conditioning system that operate during the peak design period must be listed. Included are supply/return/exhaust fans in packaged equipment. Economizer fans that do not operate at peak are excluded. Also excluded are all fans that are manually switched and all fans that are not directly associated with moving conditioned air to/from the space-conditioning system, such as condenser fans and cooling tower fans.

If the total horsepower of all fans in the system is less than 25 HP, then this should be noted in the **FAN DESCRIPTION** column and the rest of this section left blank. If the total system horsepower is not obvious, such as when a VAV system has many fan-powered boxes, then this section must be completed.

1. **COLUMN A - FAN DESCRIPTION** lists the equipment tag or other name associated with each fan.
2. **COLUMN B - DESIGN BRAKE HORSEPOWER** lists the brake horsepower, excluding drive losses, as determined from manufacturer's data.

   For dual-fan, dual-duct systems, the heating fan horsepower may be the (reduced) horsepower at the time of the cooling peak. If unknown, it may be assumed to be 35 percent of design. If this fan will be shut down during the cooling peak, enter 0 in Column B.

   If the system has fan-powered VAV boxes, the VAV box power must be included if these fans run during the cooling peak. The power of all boxes may be summed and listed on a single line. If the manufacturer lists power consumption in watts, then the wattage sum may be entered directly in Column F. Horsepower must still be entered in Column B if the designer intends to show that total system has less than 25 HP.

3. **COLUMNS C & D - EFFICIENCY** lists the efficiency of the **MOTOR** and **DRIVE**. The default for a direct drive is 1.0; belt drive is 0.97. If a variable-speed or variable-frequency drive is used, the drive efficiency should be multiplied by that device's efficiency.

4. **COLUMN E - NUMBER OF FANS** lists the number of identical fans included in this line.

   COLUMN F - PEAK WATTS is calculated as:

   (BHP x Number x 746W/HP)$(E_m \times E_d)$

   Where E_m and E_d are the efficiency of the motor and the drive, respectively.

5. **COLUMN G - CFM** is the design supply airflow at the cooling peak. This field is left blank for return fans, exhaust fans, or other fans that do not add to the net air supply to a space. (Note that power consumption for returns and exhausts is accounted for in Column B).

   For dual-duct systems, the airflow must include the hot deck airflow at the time of the cooling peak. For VAV systems with fan powered boxes, the airflow of the box fan may or may not be allowable depending on the configuration (see Section 4.2.2C).

6. **TOTALS** are provided for both PEAK WATTS (Column F) and CFM (Column G).

7. **TOTAL FAN SYSTEM POWER DEMAND, WATTS/CFM** is calculated by dividing the total PEAK WATTS (Column F) by the total CFM (Column G). To comply, total space-conditioning system power demands must not exceed 0.8 W/cfm for constant volume systems, or 1.25 W/cfm for VAV systems.

4.3.5 MECH-5: Mechanical Distribution Summary (Performance Use Only)

This form is used to verify duct tightness by the installer and/or HERS rater (third-party). Compliance credit requires third-party field verification.

A. MECH-5

Verified Duct Tightness by Installer

1. **DUCT LEAKAGE REDUCTION –** The installer must check this box if duct leakage reduction was used for determining compliance and the installer has tested the duct leakage.

   a. **Test Leakage –** enter the actual measured duct leakage value.

2. **FAN FLOW**

   a. **Calculated Fan Flow –** enter the calculated fan flow either by multiplying 400cfm/ton times the number of tons of cooling or by entering 21.7 times the heating capacity of the unit being stalled in kBtuh. In case of more than one separate fan flow unit calculate the fan flow for each separately and enter the value in the Measured Values column.

   b. **Measured Fan Flow –** enter the actual fan flow measured value in the Measured Values column.

   c. **Leakage Fraction –** enter the leakage fraction by dividing the Test Leakage by either the calculated or measured fan flow. Enter the value in the Measured Values column.

   d. **Pass or Fail –** check the "Pass" box if duct leakage is less than 6%, otherwise, check the "Fail" box.

3. **Tests Performed –** enter the type of diagnostic test performed. For this form, enter the words "Duct Leakage".

4. **Signature and Date** –enter the signature of the installer and date of the test.

5. **Name of Installing Contractor or Subcontractor**- enter the name of the company of the contractor of subcontractor.

B. HERS Rater Compliance Statement

The HERS rater fills out the following information.

1. **BUILDING TESTED –** Check this box if duct leakage reduction was used for compliance credit and the HERS Rater has tested the ducts for leakage and field verified the proper installation practice.
    a. **Supply Duct R-value** – Enter the minimum R-value used in supply ducts.
    b. **Return Duct R-value** – Enter the minimum R-value used in return ducts.
    c. **Distribution System –** Check box if distribution system is fully ducted (it does not use building cavities, support platforms for air handlers, or plenums defined or constructed with materials other than sealed sheet metal, in lieu of ducts).
    d. **Duct Connections -** Check box if cloth backed, rubber adhesive duct tape is installed and it has been verified that mastic and drawbands are used in combination with the cloth backed rubber adhesive duct tape to seal leaks at duct connections. Do not complete or sign this form if cloth backed rubber adhesive tape is used without mastic or without drawbands.
    e. **Compliance Credit –** Check box if the minimum requirements for duct leakage reduction are met ("Pass" box is checked at end of following test documentation). Credit is given in performance approach only.
2. **Fan Flow**
    a. **Calculated Fan Flow** – enter the calculated fan flow either by multiplying 400cfm/ton times the number of tons of cooling or by entering 21.7 times the heating capacity of the unit being stalled in kBtuh. If more than one separate fan flow unit calculate the fan flow for each separately and enter the value in the Measured Values column.
    b. **Measured Fan Flow –** enter the actual fan flow measured value in the Measured Values column.
    c. **Leakage Fraction –** enter the leakage fraction by dividing the Test Leakage by either the calculated or measured fan flow. Enter the value in the Measured Values column.
    d. **Pass or Fail –** check the "Pass" box if duct leakage is less than 6%, otherwise check the "Fail" box.
3. **Tests Performed –** enter the type of diagnostic test performed (for the MECH-5 enter the words "Duct Leakage").
4. **Signature and Date –**enter the signature of the HERS Rater and date of the test.
5. **Name of the HERS Rater –** Print the name of the HERS rater.

4.4 Mechanical Inspection

The mechanical building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the MECH-1 Certificate of Compliance form printed on the plans (See Section 4.3.1). Included on the MECH-1 are “Notes to Field” that are provided by the plan checker to alert the inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I.

5 Lighting Systems

5.0 Summary

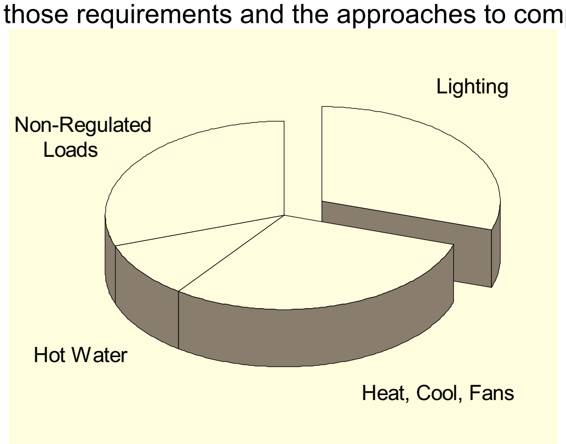
This chapter covers the Energy Efficiency Standards that affect lighting design and installation, including lighting controls. It is addressed primarily to lighting designers or electrical engineers and to building department personnel responsible for lighting and electrical plan checking and inspection. Additional information is found in Chapters 2 and 6.

The Introduction, Section 5.1 explains the alternative compliance approaches for lighting and introduces the basic lighting concepts necessary to understand the requirements. The Lighting Design Procedures Section 5.2 covers the mandatory, prescriptive, and performance requirements for the lighting systems. For the convenience of designers, a summary of the most important requirements for design and layout of the lighting and control concepts is included. The Lighting Plan Check Documents Section 5.3 describes the information that must be included in the building plans to show compliance with the *Standards*. The compliance forms are presented and discussed. The Lighting Inspection Section 5.4 refers to the Inspection Checklist in Appendix I identifying the items that the inspector will verify in the field.

Lighting is one of the single largest consumers of energy (kilowatt-hours) in a commercial building (Figure 5-1). The effective reduction of this energy use, without compromising the quality of lighting or task work, is the objective of the lighting energy standards. These standards are the result of the involvement of many representatives of the lighting design and manufacturing community, and of building departments across the state. A great deal of effort has been devoted to making the lighting requirements practical and realistic. This chapter summarizes those requirements and the approaches to complying with them.

Figure 5-1– Lighting Energy Use

Lighting accounts for 29% of all commercial building electricity use in California. Energy Efficiency Report, October 1990, California Energy Commission Publication No. 400-90-003



5.1 Lighting Compliance

The primary mechanism for regulating lighting energy under the *Standards* is to limit the allowable lighting power (watts) installed in the building. Other mechanisms require basic equipment efficiency, and require that the lighting is controlled to permit efficient operation.

Mandatory Measures apply to all lighting systems and equipment (§119, §130, §131 and §132). These requirements may include manual switching, daylit area switching, automatic shut-off controls, and tandem wiring for ballasts. The mandatory requirements must be met under either the prescriptive or performance approach.

Allowed Lighting Power for a building is determined by one of four methods:

Complete Building Method: applicable when the entire building's lighting system is designed and permitted at one time, and when at least 90% of the building is one primary type of use. In some cases the Complete Building Method may be used for an entire tenant space in a multi-tenant building. A single lighting power value governs the entire building (§146(b)1). See Section 5.2.2A for other applications of the complete building method. See Section 5.1.2 and Appendix G for definition of Entire Building.

Area Category Method: applicable for any permit situation, including tenant improvements. Lighting power values are assigned to each of the major function areas of a building (offices, lobbies, corridors, etc.) (§146(b)2).

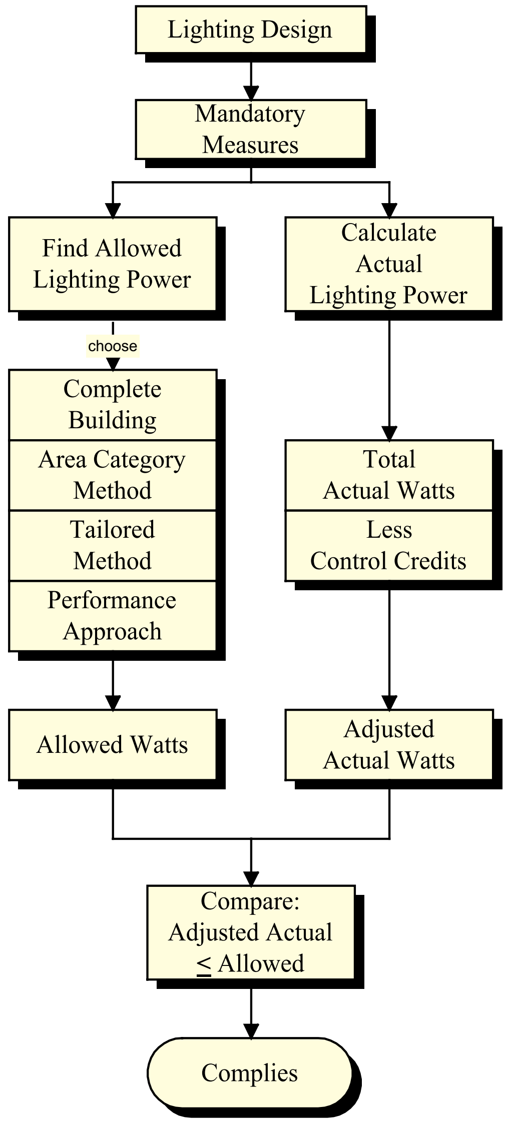
Tailored Method: applicable when additional flexibility is needed to accommodate special task lighting needs. Lighting power allowances are determined room-by-room and task-by-task (§146(b)3).

Performance Approach: applicable when the designer uses an approved computer program to demonstrate that the proposed building's energy consumption, including lighting power, meets the energy budget. The performance approach requires the use of an *Energy Commission* certified computer program and may only be used to model the performance of lighting systems that are covered under the building permit application (see Section 5.2.3).

Actual Lighting Power (Adjusted) is based on total design wattage of lighting, less adjustments for any lighting control credits taken for non-mandatory controls, such as occupant-sensing devices or automatic daylighting controls (§146(a)).

The Actual Lighting Power (Adjusted) must not exceed the Allowed Lighting Power for the lighting system to comply.

Figure 5-2– Lighting Compliance Flowchart



5.1.1 Basic Lighting Concepts and Definitions

This section includes key concepts and definitions from the *Standards* that apply to the lighting and control systems.

A. Definitions

Included in this section are definitions of terms other than occupancy type and terms specific to controls that have application to compliance with the lighting requirements of the *Standards*.

Accessible *is having access thereto, but which first may require removal or opening of access panels, doors, or similar obstructions.*

Annunciated *is a visual signaling device that indicates the on, off, or other status of a load.*

Chandeliers *(see Ornamental Chandeliers)*

Complete Building *is an entire building with one occupancy making up 90 percent of the conditioned floor area (see also Entire Building).*

Daylit Area *is the space on the floor that is the larger of 1 plus 2, or 3;*

a) *For areas daylit by vertical glazing, the daylit area has a length of 15 feet, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one-half the distance to the closest skylight or vertical glazing, whichever is least.*

b) *For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one-half the horizontal distance to the edge of the closest skylight or vertical glazing.*

c) *The daylit area calculated using a method approved by the commission.*

.

Display Lighting *is lighting confined to the area of a display that provides a higher level of illuminance than the level of surrounding ambient illuminance.*

Display, Public Area *is an area for the display of artwork, theme displays, and architectural surfaces in dining and other areas of public access, excluding restrooms and separate banquet rooms.*

Display, Sales Feature *is an item or items that requires special highlighting to visually attract attention and that is visually set apart from the surrounding area.*

Display, Sales Feature Floor *is a feature display in a retail store, wholesale store, or showroom that requires display lighting.*

Display, Sales Feature Wall *are the wall display areas, in a retail or wholesale space, that are in the vertical plane of permanent walls or partitions, and that are open shelving feature displays or faces of internally illuminated transparent feature display cases within the Gross Sales Wall Area.*

Effective Aperture (EA) *is (1) for windows, the visible light transmittance (VLT) times the window wall ratio; and (2) for skylights, the well index times the VLT times the skylight area times 0.85 divided by the gross exterior roof area.*

Efficacy *is the ratio of light from a lamp to the electrical power consumed (including ballast losses), expressed in lumens per watt.*

Entire Building *is the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all existing conditioned and unconditioned space within the structure.*

High Bay *is a space with luminaires 25 feet or more above the floor.*

Illuminated Face *is a side of an exit sign that has the word "EXIT" on it.*

Low Bay *is a space with luminaires less than 25 feet above the floor.*

Luminaire *is a complete lighting unit consisting of a lamp and the parts designed to distribute the light, to position and protect the lamp, and to connect the lamp to the power supply; commonly referred to as "lighting fixtures" or "instruments."*

Newly Conditioned Space *is any space being converted from unconditioned to directly conditioned or indirectly conditioned space, or any space being converted from semi-conditioned to directly conditioned or indirectly conditioned space. Newly conditioned space must comply with the requirements for an addition. See §149 for nonresidential occupancies and §152 for residential occupancies.*

Ornamental Chandeliers *are ceiling-mounted, close-to-ceiling, or suspended decorative luminaires that use glass, crystal, ornamental metals, or other decorative material and* *that typically are used in hotel/motels, restaurants, or churches as a significant element in the interior architecture.*

Poor Quality Lighting Tasks *are visual tasks that require illuminance category "E" or greater, because of the choice of a writing or printing method that produces characters that are of small size or lower contrast than good quality alternatives that are regularly used in offices.*

Primary Function Area is one of the categories listed in Table 5-5.

Private Office or **Work Area** *is an office bounded by 30-inch or higher partitions and is no more than 200 square feet.*

Public Areas *are spaces generally open to the public at large, customers, congregation members, or similar spaces, where occupants need to be prevented from controlling lights for safety, security, or business reasons.*

Readily Accessible *is capable of being reached quickly for operation, repair, or inspection, without requiring climbing or removing obstacles, or resorting to access equipment.*

Reduced Flicker Operation *is the operation of a light, in which the light has a visual flicker less than 30% for frequency and modulation.*

Room Cavity Ratio *(RCR)* *is:*

(a) for rectangular rooms;

$$\frac{5\ H\ (L\quad W)}{Area}$$

or

(b) for irregular shaped rooms

$$\frac{2.5\ H \times P}{Area}$$

Where:

L = *Length of room*

W = *Width of room*

H = *Vertical distance from the work plane to the center line of the lighting fixture*

P = *Perimeter of room*

Area = *Area of room*

Sconce *is a wall mounted decorative light fixture.*

Skylight *is glazing having a slope less than 60 degrees from the horizontal with conditioned space below, except for purposes of complying with §151(f), where a skylight is glazing having a slope not exceeding 4.76 degrees (1:12) from the horizontal.*

Task-oriented Lighting *is lighting that is designed specifically to illuminate a visual task and is generally confined to the task location.*

Throw Distance *is the distance between the luminaire and the center of the plane lit by the luminaire on a display.*

Very Valuable Merchandise *is rare or precious objects, including, but not limited to, jewelry, coins, small art objects, crystal, china, ceramics, or silver, the selling of which involves customer inspection of very fine detail from outside of a locked case.*

Visible Light Transmittance (VLT) *is the ratio (expressed as a decimal) of visible light that is transmitted through a glazing material to the light that strikes the material.*

Well Index *is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well and is calculated as follows:*

(a) for rectangular wells:

$$\frac{\textit{well height (well length} \quad \textit{well width)}}{\textit{2 x well length x well width}}$$

or

(b) for irregular shaped wells:

$$\frac{\textit{well height x well perimeter}}{\textit{4 x well area}}$$

Where the length, width, perimeter, and area are measured at the bottom of the well, and R (as used in Figure 5-7) is the weighted average reflectance of the walls of the well.

Window Wall Ratio *is the ratio of window area to the exterior wall area, measured from floor to ceiling (this definition is unique to lighting applications).*

Zone, Lighting *is a space or group of spaces within a building that has sufficiently similar requirements so that lighting can be automatically controlled in unison throughout the zone by an illumination controlling device or devices, and does not exceed one floor.*

B. Occupancy Type

The *Standards* recognize the fact that the primary function of different building occupancies require different amounts of lighting power to provide adequate illumination for their various types of visual tasks. The allowed lighting power in the *Standards* depends on the occupancy.

Each of the occupancy primary function types listed may be used to determine the lighting power density (watts per square foot) for the Area Category Method (see Table 5-4). Some of these same primary function types can also use the Complete Building Method (see Table 5-3). The Standard definitions of the occupancy types are listed below.

Auditorium: *the part of a public building where an audience sits in fixed seating, or a room, area, or building with fixed seats used for public meetings or gatherings not specifically for the viewing of dramatic performances*.

Auto Repair: *The portion of a building used to repair automotive equipment and/or vehicles, exchange parts, and may include work using an open flame or welding equipment.*

Bank/Financial Institution: *An area in a public establishment used for conducting financial transactions including the custody, loan, exchange, or issue of money, for the extension of credit, and for facilitating the transmission of funds.*

Classroom, Lecture, or Training: *A room or area where an audience or class receives instruction.*

Commercial and Industrial Storage*: A room, area, or building used for storing items.*

Convention, Conference, Multipurpose and Meeting Centers: *An assembly room, area, or building that is used for meetings, conventions and multiple purposes including, but not limited to, dramatic performances, and that has neither fixed seating nor fixed staging.*

Corridor: *A passageway or route into which compartments or rooms open.*

Dining: *A room or rooms in a restaurant or hotel/motel (other than guest rooms) where meals that are served to the customers will be consumed.*

Electrical/Mechanical Room: *A room in which the building's electrical switchbox or control panels, and/or HVAC controls or equipment is located.*

Exercise Center/Gymnasium: *A room or building equipped for gymnastics, exercise equipment, or indoor athletic activities.*

Exhibit: *A room or area that is used for exhibitions that has neither fixed seating nor fixed staging.*

General Commercial and Industrial Work: *A room, area, or building in which an art, craft, assembly or manufacturing operation is performed.*

> **High Bay**: *Luminaires 25 feet or more above the floor.*
>
> **Low Bay**: *Luminaires less than 25 feet above the floor.*

Grocery Store: *A room, area, or building that has as its primary purpose the sale of foodstuffs requiring additional preparation prior to consumption.*

Hotel Function Area: *A hotel room or area such as a hotel ballroom, meeting room, exhibit hall, or conference room, together with pre-function areas and other spaces ancillary to its function.*

Hotel Lobby: *The contiguous spaces in a hotel/motel between the main entrance and the front desk, including waiting and seating areas, and other spaces encompassing the activities normal to a hotel lobby function.*

Kitchen/Food Preparation: *A room or area with cooking facilities and/or an area where food is prepared.*

Laundry: *A place where laundering activities occur.*

Library: *A repository for literary materials, such as books, periodicals, newspapers, pamphlets and prints, kept for reading or reference.*

Locker/Dressing Room: *A room or area for changing clothing, sometimes equipped with lockers.*

Lounge/Recreation: *A room used for leisure activities, which may be associated with a restaurant or bar.*

Main Entry Lobby/Reception/Waiting: *The lobby of a building that is directly located by the main entrance of the building and includes the reception area, sitting areas, and public areas.*

Malls, Arcades and Atria: *A public passageway or concourse that provides access to rows of stores or shops.*

Medical and Clinical Care: *A room, area, or building that does not provide overnight patient care and that is used to promote the condition of being sound in body or mind through medical, dental, or psychological examination and treatment, including, but not limited to, laboratories and treatment facilities.*

Museum: *A space in which works of artistic, historical, or scientific value are cared for and exhibited.*

Office: *A room, area, or building of UBC group B occupancy other than restaurants.*

Precision Commercial or Industrial Work: *A room, area, or building in which an art, craft, assembly or manufacturing operation is performed involving visual tasks of small size or fine detail such as electronic assembly, fine woodworking, metal lathe operation, fine hand painting and finishing, egg processing operations, or tasks of similar visual difficulty.*

Reception/Waiting Area: *An area where customers or clients are greeted prior to conducting business.*

Religious Worship: *A room, area, or building for worship.*

Restaurant: *A room, area, or building that is a food establishment as defined in Section 27520 of the Health and Safety Code.*

Restroom: *A room or suite of rooms providing personal facilities such as toilets and washbasins.*

Retail And Sales: *A room, area, or building in which the primary activity is the sale of merchandise.*

School: *A building or group of buildings that is predominately classrooms and that is used by an organization that provides instruction to students.*

Stairs, Active/Inactive: *A series of steps providing passage from one level of a building to another.*

Support Area: *A room or area used as a passageway, utility room, storage space, or other type of space associated with or secondary to the function of an occupancy that is listed in these regulations.*

Theater, Motion Picture: *An assembly room, hall, or building with tiers of rising seats or steps for the showing of motion pictures.*

Theater, Performance: *An assembly room, hall, or building with tiers of rising seats or steps for the viewing of dramatic performances, lectures, musical events and similar live performances.*

Vocational Room: *A room used to provide training in a special skill to be pursued as a trade.*

Wholesale Showroom: *A room where samples of merchandise are displayed.*

C. Lighting Controls (§146(a)2)

Automatic lighting controls are an important part of the lighting requirements of the *Standards*. Some types of controls are necessary to comply with mandatory requirements (see Section 5.2.1A), while others allow designers the ability to reduce the Actual Lighting Power in their designs (see Section 5.2.4B). Several types of automatic lighting controls are required to be certified and listed by the *Energy Commission* (see Section 5.2.1A).

The following control device definitions are important for understanding the requirements of the *Standards* (§101).

Annunciated is a visual signaling device that indicates the on, off, or other status of a load. Annunciators are part of the requirements for such devices as area controls and automatic time switches when the area being controlled is not visible from the device location.

Automatic Time Switch Control Devices are devices capable of automatically turning loads off and on based on time schedules. There are many types of control devices that can perform this function.

NOTE: Some automatic time switch controls may incorporate "automatic off " and a "manual on" function such as hourly "off sweeps" after closing, or relay switches that drop out when power is interrupted. These devices would typically comply with the mandatory automatic shut-off provisions of §131(d).

Captive-Key Override is a type of lighting control in which the key that activates the override cannot be released when the lights are in the on position.

Current Limiter is a lighting control device that limits the input power of a track lighting fixture or incandescent medium screw base socket to a specific maximum level. The

Current Limiter (1) must be an integral part of the fixture, (2) must be hard-wired into the track or the incandescent medium screw base socket fixture, (3) can only be replaced by manufacturer authorized technicians, and (4) must have the voltage ampere (VA) rating clearly marked on the track or fixture.

Lighting Zone is a space or group of spaces within a building that has sufficiently similar requirements so that lighting can be automatically controlled in unison throughout the zone by an illumination controlling device or devices. *A lighting zone does not exceed one floor.* ***Multi-Scene Dimming System*** is a lighting control device that has the capability of setting light levels throughout a continuous range, and that has pre-established settings within the range. *This type of device is able to save energy by providing a convenient way to dim lights and reduce lighting power. Lighting control credits are available for such devices in hotels/motels, restaurants, auditoriums and theaters.*

Occupant-sensing Device is a device that automatically turns lights off soon after an area is vacated. Occupant sensors detect whether a room or space is occupied, and automatically turns the lights off when occupants are not present. Various techniques are used to sense the presence of an occupant, including sensing infrared radiation (heat) emitted from the occupant, ultrasonic waves that sense changes in wave patterns when the room is occupied, and microwave radiation. These devices can be used to meet mandatory measure requirements; they can also be used to obtain lighting control credit for the building.

Tuning is a lighting control device that allows authorized personnel only to select a single light level within a continuous range. *This type of device is able to save energy by providing a practical means of adjusting light output of a lighting system down to the specific level needed, rather than allowing excess illumination and consuming full power.*

5.1.2 Lighting Trade-offs

The *Standards* restrict the overall installed lighting power in the building, regardless of the compliance approach. However, there is no general restriction regarding where or how general lighting power is used. This means that installed lighting may be greater than the *Standards* allowances in some areas of the building and lower in others, as long as the total does not exceed the Allowed Lighting Power.

Example 5-1– Lighting Trade-Offs, General Lighting

Question

Under the Area Category Method, a mixed use building is determined to have an allowed lighting power of 23,500 watts. As part of this determination, an office area within the building is found to have an allowance of 1.3 watts/ft^2. One of the private offices within this area is designed with an actual lighting power density of 2.0 watts/ft2. Is this permitted?

Answer

Yes. Provided the actual lighting power of the entire building does not exceed the 23,500 watt limit, there is no limit on the individual office.

This is true for general lighting no matter what method is used to determine the allowed lighting power.

Note that in Examples 5-1and 5-2, it is not necessary to specify precisely where the watts come from when a trade-off occurs. These details are not needed for compliance; any individual trade-offs are included in the totals. It is necessary only to demonstrate that the actual watts total for the building does not exceed the total allowable. Trade-offs are not allowed with so-called use it or lose it categories of lighting. These are specific task or display lighting applications, such as chandeliers under the Area Category Method

(Section 5.2.2B) or display lighting under the Tailored Method (Section 5.2.2C), where the allowable lighting power for the application is determined from:

1. Wattage allowance specified by the *Standards*
2. Actual wattage of the fixture(s) assigned to the application

For use it or lose it applications, the allowable lighting power is the lesser of these two wattages. This means that the allowance cannot exceed the actual lighting wattage. If the actual lighting watts is lower than the allowance, the remaining watts in the allowance are not available for trade-off to other areas of the building.

Example 5-2– Lighting Trade-offs: Display Lighting Part 1

Question

A display lighting application (one of the “use it or lose it” applications) is determined to have a lighting power allowance of 350 watts. The actual luminaires specified for the display total 300 watts. How does this affect the allowed watts and the actual watts (adjusted if applicable) for the building?

Answer

The lower value, 300 watts, is shown as total allowed watts for the building. The actual lighting power is also 300 watts. There are no watts available for use through trade-offs elsewhere in the building.

Example 5-3– Lighting Trade-offs: Display Lighting Part 2

Question

A display lighting application is determined to have a lighting power allowance of 500 watts. The actual luminaires specified for the display total 600 watts. How does this affect the allowed watts and the actual watts (adjusted if applicable) for the building?

Answer

As before, the lower value, 500 watts in this case, is shown as the total allowed watts for the display. The proposed lighting power will include the full 600 watts. For the building lighting to comply, the extra 100 watts used by the display fixtures must be eliminated from elsewhere in the building.

Lighting control credits reduce the actual installed watts, making it easier to meet the allowed watts. This can have the same effect as trade-offs.

The specific calculations involved in the trade-offs discussed in this section are carried out on the compliance forms presented in Section 5.3.

There is another type of lighting trade-off available under the *Standards*. This is the ability to make trade-offs under the performance approach between the lighting system and the envelope or mechanical systems. Trade-offs can only be made when permit applications are sought for those systems involved, and where the trade-off has the effect of altering the Allowed Lighting Power for the building. When a Lighting Power Allowance is calculated using the performance approach, the allowance is treated exactly the same as an allowance determined using one of the other compliance methods.

5.2 Lighting Design Procedures

This section discusses how the requirements of the *Standards* affect lighting system design. For procedures on documenting the lighting design, including compliance forms, see Section 5.3.

5.2.1 Mandatory Measures

The mandatory features and devices must be included in the building design whether compliance is shown by the prescriptive or the performance approach. These features have been proven cost-effective over a wide range of building occupancy types.

Many of the mandatory features and devices are requirements for manufacturers of building products, who must certify the performance of their products to the *E*nergy Commission. It is the responsibility of the designer, however, to specify products that meet these requirements. Code enforcement officials, in turn, check that the mandatory features and specified devices are installed.

A. Certified Automatic Lighting Control Devices (§119)

The mandatory requirements for lighting control devices specify minimum features for automatic time switch controls, occupant-sensing devices, automatic daylighting controls, and interior photocell sensors. Many of these requirements are part of standard practice in California and should be well understood by those responsible for designing or installing lighting systems.

All automatic lighting control devices must be certified by the manufacturer before they can be installed in a building. The manufacturer must certify the devices to the *Energy Commission*. Once a device is certified, it will be listed in the Directory of Automatic Lighting Control Devices. Call the Energy Hotline at 1-800-772-3300 to obtain more information. All devices must have instructions for installation and start-up calibration, must be installed in accordance with such directions, and must have a status signal (visual or audio) that warns of failure or malfunction. Photocell sensors and other devices may be considered exempt from this requirement if the status signal is infeasible because of inadequate power.

Automatic Time Switches (ATS) (§119(c))

Automatic time switches are programmable switches that are used to automatically shut-off the lights according to pre-established schedules depending on the hours of operation of the building. The device should have the capability to store two separate programs (for weekdays and weekends). To prevent losing the time of day and the programmed schedules, the time switch must contain back-up power for at least 10 hours during power interruption.

Note: Most building automation systems can meet these requirements, provided they are certified to the *Energy Commission*.

Occupant-Sensors (§119(d))

Occupant-sensing Devices. Occupant-sensing devices shall be capable of automatically turning off all the lights in an area no more than 30 minutes after the area has been vacated. In addition, ultrasonic and microwave devices shall have a built-in mechanism that allows calibration of the sensitivity of the device to room movement in order to reduce the false sensing of occupants, and shall comply with the following requirements, as applicable:

If the device emits ultrasonic radiation as a signal for sensing occupants within an area, the device shall:

Have had a Radiation Safety Abbreviated Report submitted to the Center for Devices and Radiological Health, Federal Food and Drug Administration, under 21 Code of Federal Regulations, Section 1002.12 (1996), and a copy of the report shall have been submitted to the California Energy Commission; and

Emit no audible sound; and

Not emit ultrasound in excess of the following decibel (dB) values, measured no more than five feet from the source, on axis:

MIDFREQUENCY OF SOUND PRESSURE THIRD-OCTAVE BAND (in kHz)	MAXIMUM dB LEVEL WITHIN THIRD-OCTAVE BAND (in dB reference 20 micropascals)
Less than 20	80
20 or more to less than 25	105
25 or more to less than 31.5	110
31.5 or more	115

If the device emits microwave radiation as a signal for sensing occupants within the area, the device shall:

Comply with all applicable provisions in 47 Code of Federal Regulations, Parts 2 and 15 (1996), and have an approved Federal Communications Commission Identifier that appears on all units of the device and that has been submitted to the commission; and

Not emit radiation in excess of one milliwatt per square centimeter measured at no more than five centimeters from the emission surface of the device; and

Have permanently affixed to it installation instructions recommending that it be installed at least 12 inches from any area normally used by room occupants.

Automatic Daylighting Controls (§119(e))

Daylighting controls consist of photocell sensors that compare actual illumination levels with a reference illumination level and reduce the electric lighting until the reference level has been reached.

When automatic daylighting control devices and systems are used, they must be certified to the *Energy Commission* that they meet the following requirements:

The ability to reduce the general lighting power of the controlled area by at least 50 percent uniformly (either by separate control of multiple lamps or by dimming)

When a dimmer is used it must provide reduced flicker operation (see definitions) over the dimming range without causing premature lamp failure

For stepped dimming, provide a minimum of 3 minutes time delay between steps to prevent cycling

Single- or multiple-stepped switching controls with distinct on and off settings for each step shall include sufficient separation (dead-band) between points to prevent cycling

Interior Photocell Sensor Device (§119(f))

Daylighting control systems incorporate a photocell that measures the amount of light at a reference location. The photocell provides light level information to the controller so it can decide when to increase or decrease the electric light level.

Photocell devices must be certified to the *Energy Commission* as not having mechanical slide covers or other means that allow easy unauthorized adjusting or disabling of the photocell. In addition, they shall not be combined in a wall mounted occupant-sensing device. (This means that wall-mounted occupant-sensing devices with photocell controls can be certified as occupant-sensing devices but not interior photocell devices.)

B. Area Controls (§131(a))

The simplest way to improve lighting efficiency is to turn off the lights when they are not in use. All lighting systems must have switching or control capabilities to allow lights to be turned off when they are not needed.

Room Switching (§131(a)1)

Independent lighting controls are required for each area enclosed by ceiling height partitions. In the simplest case, this means that each room must have its own switching; gang switching of several rooms is not allowed. Switching or control device shall be readily accessible, located so that the person using the device can see the lights or area controlled by a switch, or the area being lit is annunciated and manually operated or automatically controlled by an occupant sensing device that meets the requirements of §119 (d).

Accessibility (§131(a)1A & B)

All manually operated switching devices must be located so that personnel can see the controlled area when operating the switch(es). When not located within view of the lights or areas, the switch shall be annunciated to indicate the status of the lights (on or off).

Security or Emergency (§131(a) Exception No. 1)

Lighting in areas within a building that must be continuously illuminated for reasons of building security or emergency egress are exempt from the switching requirements for a maximum of 0.5 watts per square foot along the path of egress. These lights must be installed in areas designated as security or emergency egress areas on the plans, and must be controlled by switches accessible only to authorized personnel. The remaining lighting in the area, however, is still subject to the area switching requirements.

Public Areas (§131(a) Exception No. 2)

In public areas, such as building lobbies, concourses, etc., the switches may be located in areas accessible only to authorized personnel.

Other Devices (§131(a)2)

If the room switching operates in conjunction with any other kind of lighting control device, there are two other requirements: 1) the other control device must allow the room switching to override its action, and 2) if the other control device is automatic, it must automatically reset to its normal operation mode without any further action.

For example, if there is an automatic control system that sweeps all the lights off in a group of offices at a certain hour, the room switch in any individual office must be able to override the sweep and turn the office's lights back on. The next time the automatic control sweeps the lights off, however, the override for that individual office must not remain in effect but must return to automatic mode and shut the lights off.

Example 5-4– Shut-off Control Override

Question

A 5,000 square foot building will be equipped with an automatic control device to shut off the lights, in compliance with §131(b)--building shut-off. How are the local switches supposed to respond when an occupant wishes to turn on lights after the lights are shut off?

Answer

The local switch (as specified in §131(a)) must allow the occupant to override the shut off and turn on the lights in their area (§131(a)2.A.), Following the override, the automatic function of the shut-off must resume, so that when the automatic control sweeps the lights off, these lights will be shut off unless the local switch again overrides the shut-off (§131(a)2.B.).

Example ***5****-5– Manual Switches and Automatic Controls*

Question

The card access system of a proposed building will automatically turn on the lobby and corridor lights when activated by someone entering the building after hours. In addition, the lobby and corridor lights are on an automatic time switch control. Are manual switches required for the lobby and corridor?

Answer

Yes. The manual switch is still required under the area control mandatory measure requirement. Furthermore, the manual switch must be able to turn off the lights when either the automatic time switch control or card access system has turned them on. The automatic devices must be automatically reset.

C. Bi-Level Switching §131(b)

Most areas in buildings must be controlled so that the connected lighting load may be reduced by at least 50 percent in a reasonably uniform illumination pattern. The intent of this requirement is to achieve the reduction without losing use of any part of the space (see Figure 5-3). This bi-level switching may be achieved in a variety of ways, such as:

- Using dimming controls
- Switching the middle lamps of three lamp luminaires independently of outer lamps
- Separately switching "on" alternate rows of luminaires
- Separately switching "on" every other luminaire in each row (checkerboard)
- Separately switching lamps in each luminaire

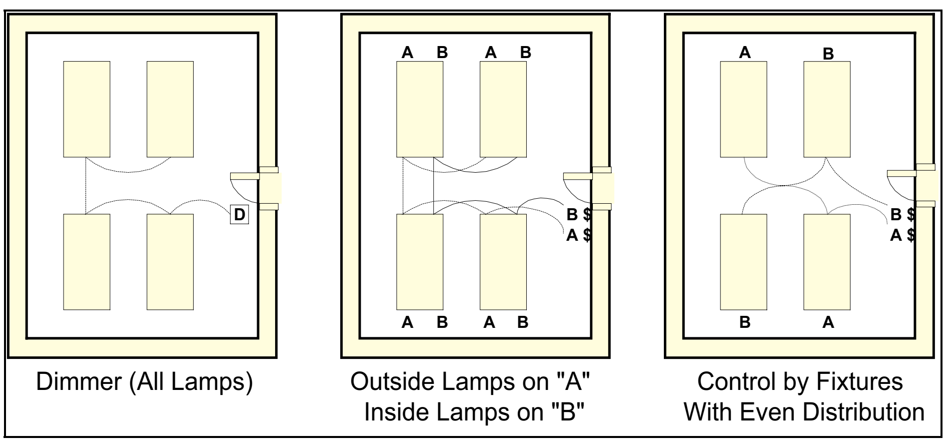
Bi-level switching is not required when:

- The lighting power density is less than 0.8 watts per square foot, or
- The area has only one light source (luminaire),
- The area is less than 100 square feet,
- The area is a corridor.

D. Daylit Areas (§131(c))

The control of electric lighting in the area where daylighting enters a building through windows or skylights is addressed in the *Standards*. It falls under the mandatory requirement for separate switching in daylit areas, and may receive credit under the optional automatic controls credits. Under the mandatory measures, where an enclosed space is greater than 250 square feet, the electric lighting within daylit area must be switched so that the lights can be controlled separately from the non-daylit areas (see definition of daylit area below). It is acceptable to achieve control in the daylit area by being able to shut off at least 50 percent of the lamps within the daylit area. This must be done by a control dedicated to serving only luminaires in the daylit area. If there are separate daylit areas for windows and skylights, they must be controlled separately.

Figure 5-3– Bi-Level Switching



The daylit area switching requirements are in addition to the bi-level switching requirements. Taken together, there are at least three ways to comply (see Figure 5.4) With the *4 Switch Option*, the bi-level switching is provided separately to the daylit area (within fifteen feet of the windows) and to the non-daylit area. The *3 Switch Option* also meets the requirements because switch "1" controls at least 50 percent of the lighting in the daylit area. Switch "2" controls the remainder of the lights in the daylit area and half of the lights in the non-daylit area. Switch "3" controls the remainder of lights in the non-daylit area. The *Dimmer Switch Option* controls the daylit and non-daylit areas separately, and the dimmer takes care of the bi-level illumination requirement. Daylight switching must be applied to a fixture if any portion of that fixture is within the daylit area.

The only exception to the requirement of providing the separate control to daylit areas is when there is not enough daylight to be used effectively. This is decided in one of two ways:

1. When the daylight to a window or skylight is so obstructed by adjacent structures or natural objects that the effective use of daylighting is not reasonable. This determination must be made by the local enforcement agency.

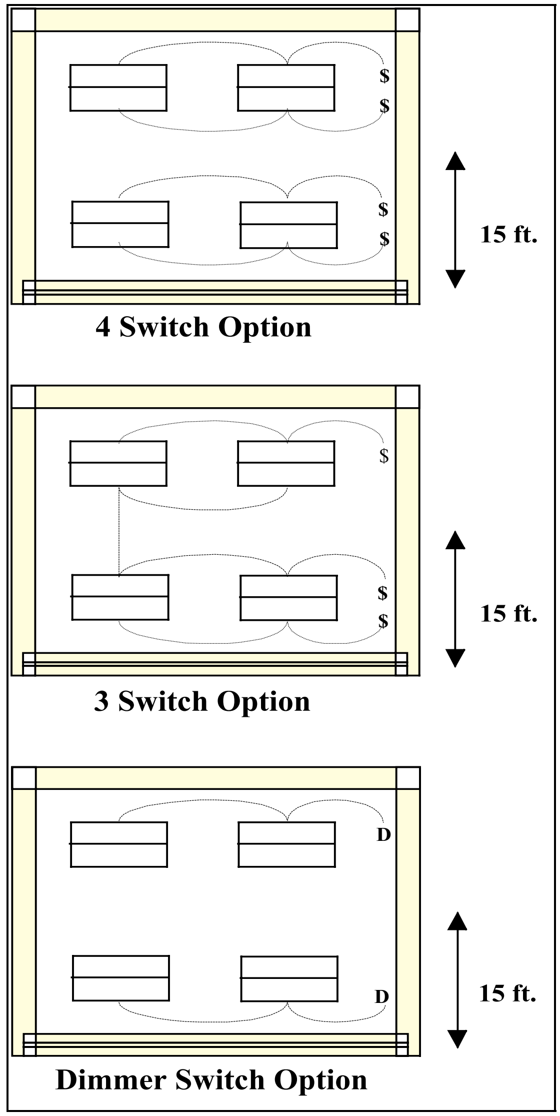
2. When the effective aperture of the window is less than 0.1 (or of the skylight is less than 0.01). A low effective aperture prevents usable daylight from entering the area; it is caused by small glazing area, low transmission glazing materials, or a combination of both. (See definition of ***Effective Aperture*** below.)

Daylit Area is the space on the floor that is the larger of (a) plus (b), or (c);

(a) For areas daylit by vertical glazing, the daylit area has a length of 15 feet, or the distance on the floor, perpendicular to the glazing, to the nearest 60-inch or higher opaque partition, whichever is less; and a width of the window plus either 2 feet on each side, the distance to an opaque partition, or one half the distance to the closest skylight or vertical glazing, whichever is least (see Figure 5-5).

(b) For areas daylit by horizontal glazing, the daylit area is the footprint of the skylight plus, in each of the lateral and longitudinal dimensions of the skylight, the lesser of the floor-to-ceiling height, the distance to the nearest 60-inch or higher opaque partition, or one-half the horizontal distance to the edge of the closest skylight or vertical glazing (see Figure 5-6– Skylight Daylit Area). The daylit area calculated using a method approved by the *E*nergy Commission. Such methods include DOE 2.1D and E, Superlite, Quicklite and other computer-based models that determine the daylit area based on modeling the features of the space.

Figure 5-4– Combined Bi-level and Daylit Area Switching



Effective Aperture (EA) for windows equates to the visible light transmittance (VLT) times the window wall ratio. The EA for windows is calculated for each room with daylighting (see Table 5-1). The window wall ratio used in calculating EA is determined from the Exterior Wall Area of the room with the window(s) (measured from floor to ceiling), and from the windows area. Windows with an EA greater than or equal to 0.1 indicate sufficient daylight is available to require a separate control for the daylit area.

For the EA calculation of a skylight see Table 5-1.

Note: *The skylight-to-roof area ratio is determined from the skylight area and the gross exterior roof area of each daylit space. 0.85 is a dirt depreciation factor for the skylight.*

See following pages for discussion of Well Index and VLT (Visible Light Transmittance). See Section 3.1.2A for ***Surface Definition*** terms.

Table 5-1 - Effective Aperture Matrix

Is Adequate Daylighting Available?				
	WINDOWS (Vertical Glazing			
	Window/Wall Ratio			
Glazing Type	< 0.10	0.10 to 0.20	0.20 to 0.40	> 0.40
VLT > 0.60	NO	CALC*	YES	YES
VLT 0.35 to 0.59	NO	CALC*	CALC*	YES
VLT < 0.35	NO	NO	CALC*	CALC*
*Window EA = VLT x Window Wall Ratio				
	SKYLIGHTS (Horizontal Glazing)			
	Skylight-to-Roof Area Ratio			
Glazing Type	< 0.01	0.01 to 0.03	> 0.03	
VLT > 0.630	NO	CALC**	YES	
VLT 0.35 to 0.59	NO	CALC**	YES	
VLT < 0.35	NO	CALC**	CALC**	
**Skylight EA= Efficiency of Well x VLT x Skylight-to-Roof Area Ratio x .85				
NOTE: This skylight matrix does not account for well index (WI). If the skylight has a light well, the EA could be substantially lower. It is recommended that the EA be calculated in such cases.				

Example 5-6– Effective Aperture Matrix

Question

A room has a window area of 90 ft² . The exterior wall has a gross area of 180 ft². The window glazing has a visible light transmittance (VLT) of 0.31. Do the daylit area switching requirements apply in this room?

Answer

Yes. The window wall ratio (WWR) for the room is 90 ft² / 180 ft² = 0.50. The effective aperture, EA = 0.50 x 0.31 = 0.155, which is greater than 0.1 (exception for inadequate daylight does not apply). (With a WWR of 0.50 and a VLT of less than 0.35, the matrix in Table 5-1also indicates that the EA is high enough that adequate daylighting is available). Daylighting control credits are available for the room (Table 5-10).

Table 5-1, above, can be used as a simplified method for calculating the EA. It indicates when the EA is low enough to invoke the exception to the requirements for daylight switching control. Each vertical column of the table corresponds to a window wall ratio or skylight-to-roof ratio range. Each horizontal row of the matrix corresponds to a range of VLTs. In questionable cases, indicated by "DO CALC" on Table 5-1, the EA should be calculated to obtain a precise answer as to whether the daylit area must be separately controlled.

If, instead of using Table 5-1, the EA is to be calculated, the following terms must also be understood.

Visible Light Transmittance (VLT) is a property of the glass or plastic glazing material. The value of VLT for a given material is found in the manufacturer's literature.

Example 5-7– Skylight/Daylit Area

Question

What is the daylit area associated with the skylight shown in Figure 5-6?

Answer

The daylit area of the skylight is calculated from the length and width of the skylight footprint, and from the ceiling height (there are no opaque partitions or nearby windows/skylights). The length of the daylit area is the length of the skylight (10') plus the floor-to-ceiling height on each end (11' + 11'), for a total daylit area length of 32'. The width of the daylit area is the width of the skylight (5') plus the floor-to-ceiling height on each end (11' + 11') for a total daylit area length of 27'. The daylit area is its length times its width, or 32' x 27' = 864 ft² .

Well Index (Efficiency of Well) is the ratio of the amount of visible light leaving a skylight well to the amount of visible light entering the skylight well. The Well Index is calculated as follows:

(a) For rectangular wells:

$$\text{Well Index} \quad \frac{\text{well height (well length} \quad \text{well width)}}{\text{2 x well length x well width}}$$

Or

(b) for irregular shaped wells:

$$\text{Well Index} \quad \frac{\text{well height x well perimeter}}{\text{4 x well area}}$$

where the length, width, perimeter and area are measured at the bottom of the well.

Figure 5-5– Window Daylit Area

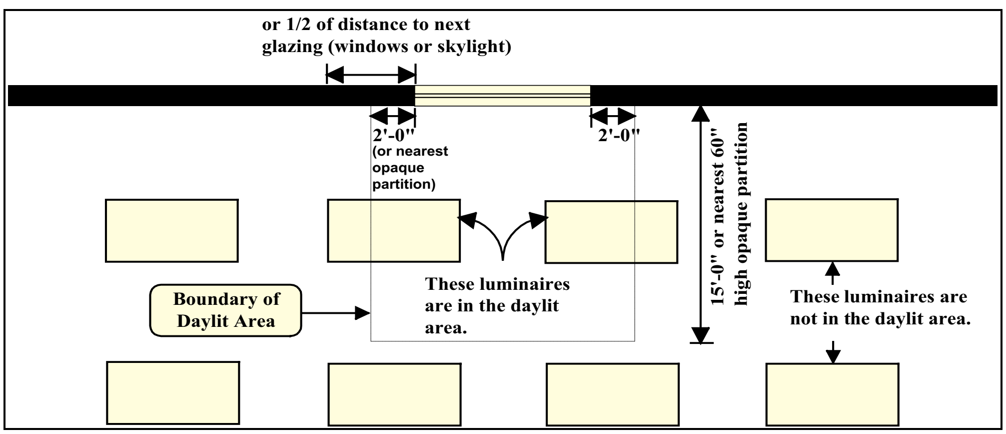


Figure 5-6– Skylight Daylit Area

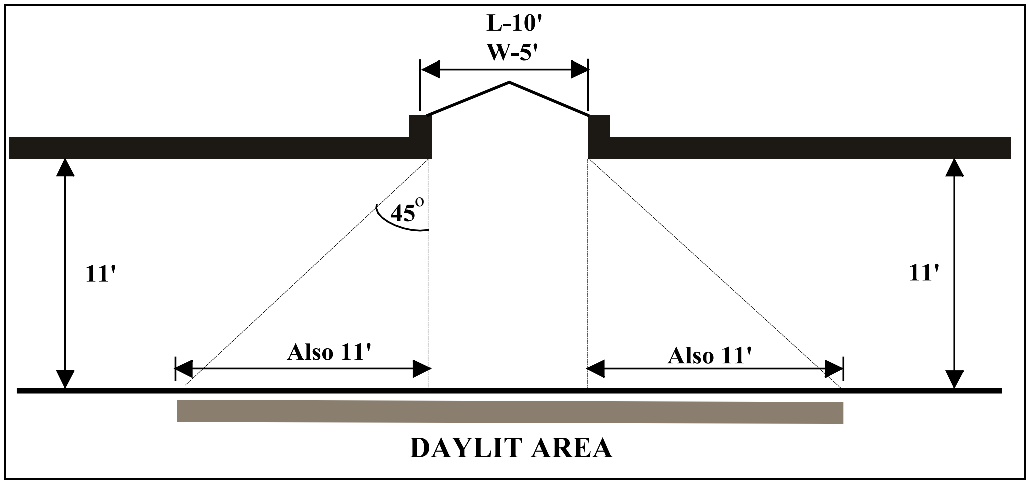
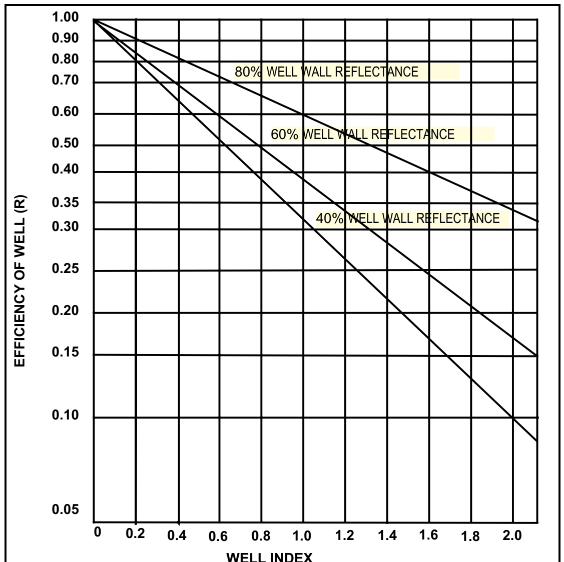


Figure 5-7– Efficiency of Well Graph



Source: Fig 7-38, *IES Lighting Handbook,* 1984 Reference Volume

The area weighted average reflectance [of the walls of the well (R)] is the average calculated by the area of reflectance of all surfaces associated with a skylight. Reflectance is based on the surface color and type. To acquire information on the values for various surface types refer to the 1987 Illumination Engineering Society Handbook, or use the Munsell reflectance rating system. See Figure 5-7 to determine the efficiency of well.

Example 5-8– Skylight Effective Aperture

Question

A skylight well has base dimensions of 6 ft by 8 ft. The well height is 4 ft. The inside surface of the well is painted with a blue paint having a reflectance of 50%. The skylight area is 16 ft^2. It has a visible light transmittance of 35%. The gross exterior roof area of the room is 200 ft^2. What is the effective aperture?

Answer

Skylight EA= Efficiency of Well x VLT x Skylight-to-Roof Area Ratio x .85

To arrive at the Efficiency of Well, first calculate the Well Index:

$$\text{Well index} = \frac{\text{Well height (well length + well width)}}{2 \times \text{well length} \times \text{well width}}$$

$$\frac{4\,(6 + 8)}{2 \times 6 \times 8} = .58$$

Next, find the Efficiency of Well from Figure 5-7. Enter the horizontal axis at 0.58 (Well Index from the equation above). Draw a vertical line up to the 50% reflectance (for the blue wall paint) line - interpolate midway between the 40% and 60% reflectance lines. From the intersection, draw a horizontal line towards the vertical axis to find the Efficiency of Well - 0.56.

Then calculate the Skylight-to-Roof area ratio of the room:

$$\frac{16\ ft^2}{200\ ft^2} = 0.08$$

Finally, calculate the Effective Aperture by multiplying together the Efficiency of Well, VLT, Skylight-to-Roof area ratio, and dirt depreciation (0.85).

Skylight Effective Aperture = 0.56 x 0.35 x 0.08 x 0.85 = .0133

(Note that for EA>.01, daylit area controls are required).

E. Shut-Off Controls (§131(d))

The *Standards* require a separate automatic control device (or control point with multiple point control systems), for areas not exceeding 5,000 square feet. Each floor must be equipped with a separate automatic shut-off control device.

The areas exempted from automatic shut-off are:

- Areas that must be continuously lit imply 24 hour operation, such as hotel lobbies and 24-hour, 365 day/year grocery stores where lights are never turned off.
- Areas lit in a manner requiring manual operation of the lighting system such as spaces which always have varying and unpredictable operating schedules, or spaces with lighting systems equipped with high intensity discharge (HID) lamps and where the use of the space results in unpredictable on/off operation. The space requires manual operation because of the longer start/restart time of HID lamps coupled with the unpredictable schedule.

Note: Most facilities equipped with HID lighting will not fall under this exception because an operating schedule will be reasonable to predict. A facility with a predictable operating schedule and metal halide lighting could still use automatic shut-off without posing a risk to people working or conducting business in the building

- Security or emergency egress lighting that must be continuously lit, provided it does not exceed 1/2 watt per square foot and the area is controlled by switches accessible only to authorized personnel (the security or egress area must be documented on the plans)

- Corridors, guest rooms, and lodging quarters of high-rise residential buildings or hotel/motels

The shut-off control need not be a single control, but may include automatic time switches, occupancy sensors, or other automatic controls (see Figure 5-8 and Figure 5-9.)

When an occupant-sensing device is used to meet the automatic shut-off requirement, it must be installed in accordance with manufacturer's instructions with regard to placement of the sensors.

Automatic time switches with programmable solid-state perpetual calendar control devices can also be used to meet the shut-off requirement. These devices are typically available with multiple channels of control, and may also be used to meet the mechanical system automatic time switch control requirements.

Figure 5-8– Timed Manual Override

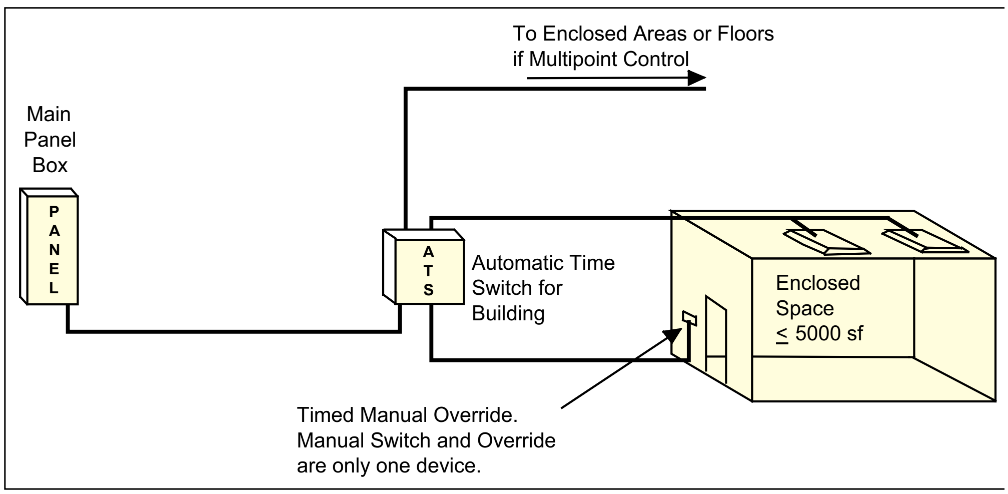
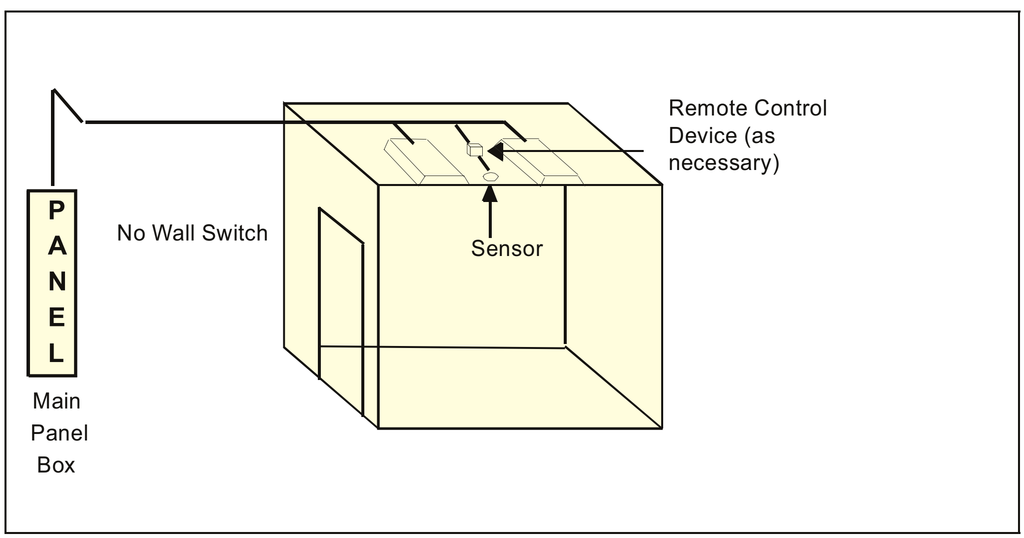


Figure 5-9– Occupant-sensing Device Shut-off



If an automatic time switch control device is used for shut-off control, it must be certified, incorporate an automatic holiday shut-off that turns off all lighting loads for at least 24 hours and then resume normal scheduled operation. Holiday scheduling is not required for: retail stores and associated malls, restaurants, grocery stores, churches, and theaters. If an automatic time switch control device is used for shut off, the control must be designed with override switching devices. The override switching devices shall:

- Control an area not exceeding 5,000 square feet on a single floor. For malls and arcades, auditoriums, single tenant retail spaces, industrial facilities, and arenas, the area controlled may not exceed 20,000 square feet.
- Be readily accessible
- Be manually operated
- Allow the operator to see the lights or area controlled or be annunciated (see definition in Section 5.1.1A)
- Provide an override for not more than 2 hours. In malls and arcades, auditoriums, single tenant retail spaces, industrial facilities, and arenas where captive-key override (see definition in Section 5.1.1A) is utilized, a 2 hours override limit is not required.

F. Display Lighting (§131(e))

Display lighting shall be separately switched on circuits that are 20 amps or less. The general lighting should be on separate switching so it will be operated without having to turn on the display lighting (as, for example, when the cleaning crew is working at night and there is no need for the displays to be lit).

G. Exterior Lights (§131(f))

The *Standards* also require automatic control of all permanently installed exterior lighting attached to or powered by the electrical service in buildings that contain conditioned space(s). The exterior lights shall be controlled by a directional photocell or an astronomical time switch that automatically turns off the exterior lighting when daylight is available. A building automation system with a program that is capable of duplicating the action of an astronomical time switch is acceptable.

When determining the type of control to use, night time ambient lighting such as street lights, sports stadiums, car headlights, etc. should be considered because they may effect the performance of a directional photocell.

Lights in parking garages, tunnels, and large covered areas that are required to be on during the day are exempt from this requirement.

H. Tandem Wiring (§132)

Pairs of one-lamp or three-lamp recessed fluorescent luminaires that are 1) on the same switch control, 2) in the same enclosed area and 3) within 10 feet of each other in an accessible ceiling space, must be tandem wired (see Figure 5-10). Single lamp ballasts should not be used.

Tandem wiring refers to the arrangement where a ballast operates a lamp in one luminaire and a lamp in an adjacent luminaire. Surface or pendant mounted fixtures that are continuous with each other must also be tandem.

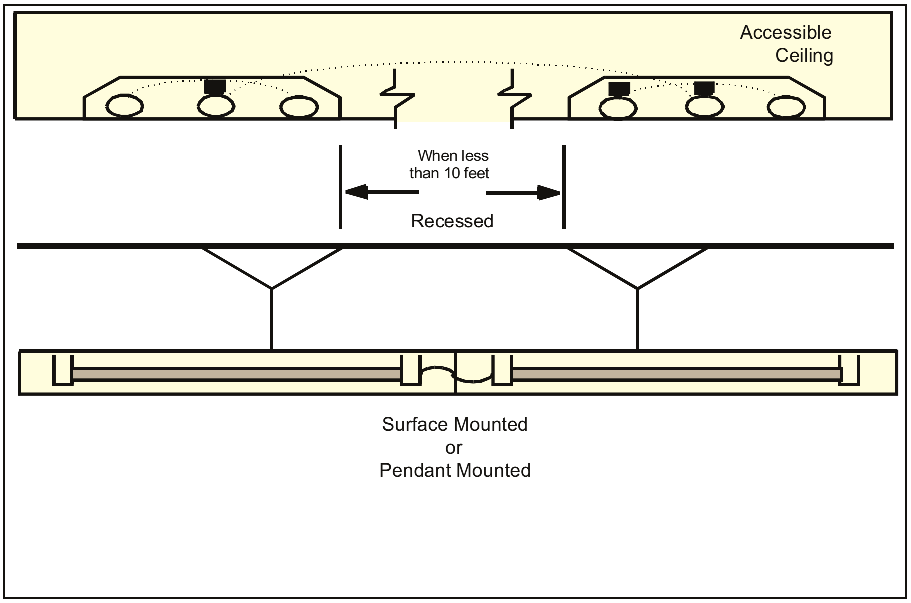
Luminaires that are exempt from this requirement are:

- Surface or pendant mounted luminaires that are not continuous
- Fluorescent luminaires that use electronic high frequency ballasts

Single lamp ballasts may be used in emergency battery-ballast units and when there are an odd number of lamps or where there are multiple groups of bi-level switching and the control scheme produces two one-lamp ballasts adjacent to each other, but controlled by different switches.

Exit signs are exempt.

Figure 5-10– Tandem Wiring



I. Certified Ballasts and Luminaires

Fluorescent lamp ballasts and luminaires with fluorescent lamp ballasts are regulated by the Appliance Efficiency Regulations. Those certified to the *Energy Commission* are listed in the efficiency database. See California *Energy Commission* web page or call the Energy Hotline at 1-800-772-3300 to obtain more information. All standard wattage four-foot and eight-foot lamp and ballast combinations commonly installed in nonresidential buildings are included in the ballast efficiency database.

J. High Rise Residential Living Quarters and Hotel/Motel Guest Rooms - General (§130)

The *Standards* require that lighting in high-rise residential living quarters and in hotel/motel guest rooms comply with lighting requirements similar to the lighting requirements of the Residential Standards.

K. Kitchen Lighting (§130(b)1)

The *Standards* require that general lighting in high rise residential or hotel/motel kitchens have an efficacy of at least 40 lumens per watt and be controlled by the most accessible switch(es) in the kitchen. The light switch location determines how the occupant will use the lighting. If more than one set of light fixtures provide general lighting, those controlled by the most accessible switch are considered general lighting. Luminaires used only for specific decorative effects (and which are not the only luminaires in the kitchen) need not meet this requirement.

General lighting is lighting designed to provide a substantially uniform level of light distribution throughout a space. This can be achieved by light fixtures in the ceiling or around the perimeter of the room. Lighting fixtures under cabinets may meet the general lighting requirements if they provide uniform light distribution in the kitchen (see Figure 5-11). A luminaire which is the only lighting in a kitchen will be considered general lighting.

Example 5-9– Energy-efficient Kitchen Lighting, General

Question

What is recommended for designing and providing an energy efficient kitchen? I especially want the lighting design to provide an aesthetically pleasing appearance, sufficient light for basic kitchen tasks, and be energy efficient while also complying with the *Standards*. What is the recommended practice for achieving this goal?

Answer

It is recommended that the builder use one of the following four ways to show compliance:

1. Design and install only high-efficacy luminaires in the kitchen. This scenario meets the code requirement in the most straightforward manner. When kitchen lighting includes both high-efficacy sources and low-efficacy sources, the design may not meet these requirements. The second through fourth ways of showing compliance apply to kitchens with both high- and low-efficacy sources.
2. Provide at least 1.2 Watts per square foot (total square feet of the accessible kitchen floor and countertop areas) of light from high-efficacy sources, and ensure that, in the judgment of the building department plan checker, the lamps in those fixtures produce a substantially uniform pattern of lighting on kitchen work surfaces (please note that this is not a code requirement but a recommendation).
3. Make sure that at least 50% of the kitchen lighting wattage is high-efficacy, and that, in the judgment of the building department plan checker, the lamps in those fixtures produce a substantially uniform pattern of lighting on kitchen work surfaces (please note that this is not a code requirement but a recommendation).
4. If you wish to be certain you have provided an “energy efficient kitchen…an aesthetically pleasing appearance…sufficient light for basic kitchen tasks…while also complying with the *Standards*,” it is recommended that you use the same procedures used by professional lighting designers (again, the intent of this recommendation is not that these procedures become a standard part of builder submittals, but rather that they are used to provide the best possible solutions for builders who wish to provide high quality lighting designs).

These procedures account for the characteristics of the room and the design and location of the specific high-efficacy luminaires that will be installed as the best method to determine if there is both sufficient and uniform light. A recognized lighting authority, the Illuminating Engineers Society (IES), provides guidelines for good lighting design in their Lighting Handbook, Reference & Application, 10th Edition.

IES guidelines recommend that at least 30 footcandles of light be provided for seeing tasks in kitchens. Visual tasks include, but are not limited to, the basic kitchen tasks that are described in the Energy Commission’s *Residential Manual* as preparing meals and washing dishes. These tasks typically occur on accessible kitchen countertops, the tops of ranges and in sinks, where food preparation, recipe reading, cooking, cleaning and related meal preparation activities take place, as well as at the front of kitchen cabinets so that the contents of the cabinet are discernable.

To clearly demonstrate compliance with the *Standards* to a building department, the builder may provide a lighting layout design that includes a point-by-point illuminance grid for the high-efficacy lighting. To do this properly, this grid must account for the room geometry, fixture placement, coefficient of utilization (CU) of the fixtures, lamp lumens, lamp lumen depreciation, and reflectivity of all of the surfaces in the kitchen.

Uniform lighting assures that the minimum amount of light is available on all the work surfaces used in meal preparation and cleanup. Although the design should achieve 30 footcandles on most counter-height, horizontal work surfaces, there may be a few work-surfaces where the lighting levels fall below this value and the fronts of kitchen cabinets may also be below this value. Even in these locations, the lighting level provided by the high-efficacy source should not fall below the IES-recommended lower value for non-critical seeing tasks of 20 footcandles. Parts of counters that are not work surfaces, such as a corner underneath a cabinet, may have a lighting level below 20 footcandles and still meet the requirements of the standard, because meal preparation is unlikely to occur in those areas.

Manufacturers and lighting fixture representatives can often provide such a grid for a specified design. Electrical engineers who do lighting designs and professional lighting designers also often provide designs with a point-by-point illuminance grid.

The plans should identify the type of luminaire and maximum Underwriters Laboratory (UL)-rated lamp watts for each luminaire and should include dimensions and tolerances of each luminaire so that the installer, plan checker, and field inspector can all determine when the lighting installation matches the plan checker's judgment. When calculating the kitchen lighting wattage, the builder should be certain to use the maximum UL-rated wattage for each fixture.

Bathroom Lighting (§130(b)2)

The *Standards* require that each room containing a water closet must have at least one luminaire with lamps with an efficacy of at least 40 lumens per watt. As an alternative, this requirement may be met by installing the high efficacy luminaire in an adjacent room that has complementary plumbing fixtures (See Figure 5-12).

If there is more than one luminaire in the room, the high-efficacy luminaire must be switched at an entrance to the room.

Table 5-2 - Typical Efficacy of Luminaires

Light Source	Type	Rated Lamp (Watts)	Typical Efficacy (Lumens/Watt[1])
Incandescent	Standard	40 - 100	14 - 18
Incandescent	Halogen	40 - 250	20[2]
Incandescent	Halogen IR	See footnote[3]	Up to 30
Fluorescent (Lamp/Ballast Systems)[4]	Full-Size, 4' Long	32 - 40	69 - 91
	U-Shaped T-8 Bi-pin	16 - 31	78 - 90
	Compact Fluorescent	5 - 9	26 - 38
	Compact Fluorescent	13 +	42 - 58
Metal Halide	Metal Halide	32 - 175	50 - 90
High Pressure Sodium	White High Pressure Sodium	35 - 100	36 - 55

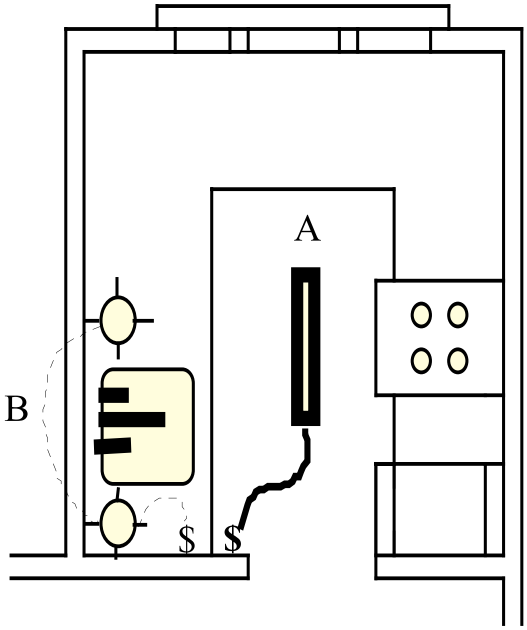
1 Includes power consumed by ballasts where applicable.

2 Halogen capsule incandescent lamps may be the most efficient light source for highlighting applications. Most halogen lamps are designed to produce a beam of directed light. Manufacturer's data typically list the "candlepower" intensity of that beam, rather than lumens (lumens measure total light output in all directions).

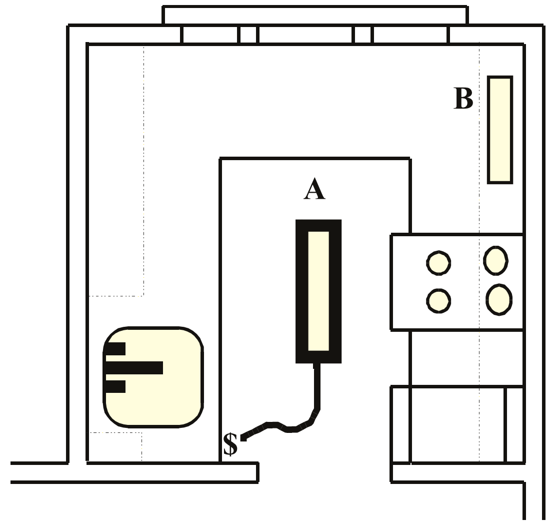
3 A new technology using infrared reflecting films on the halogen capsules has increased output up to 30 lumens/watt for some high wattage lamps.

4 Efficacy of fluorescent lighting varies depending on lamp and ballast types.

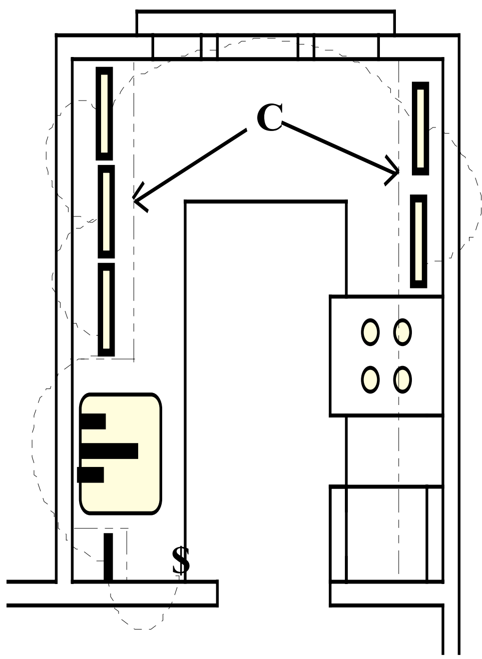
Figure 5-11– Residential and Hotel/Motel Guestroom (Kitchen Lighting Examples)



"A" must be fluorescent

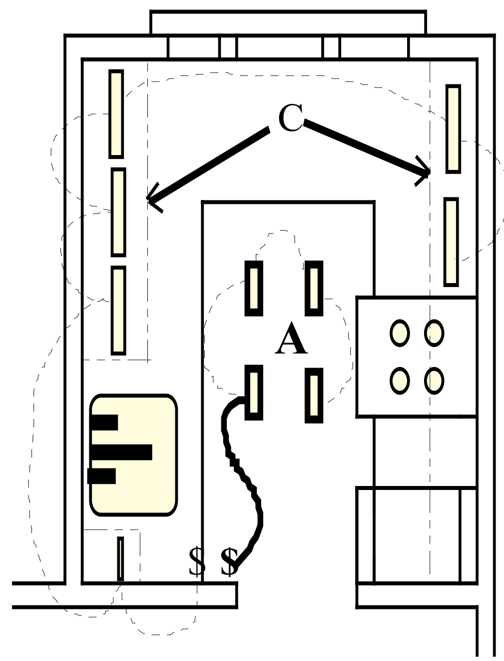


"A" must be fluorescent
"B" alone is not general lighting



All of "C" must be fluorescent

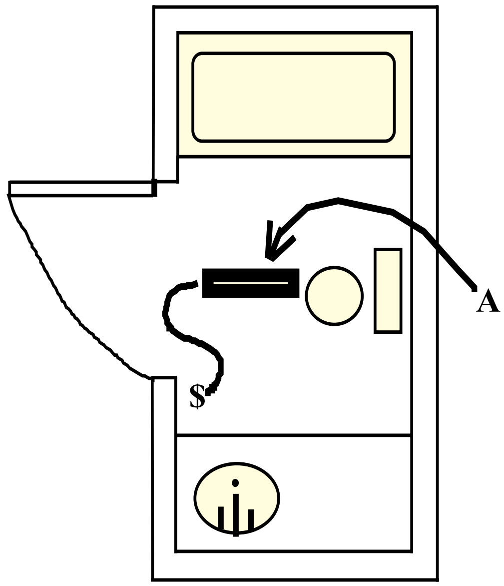
This alternative is not sufficient if 'C' does not provide sufficient illumination for the insides of cabinets.



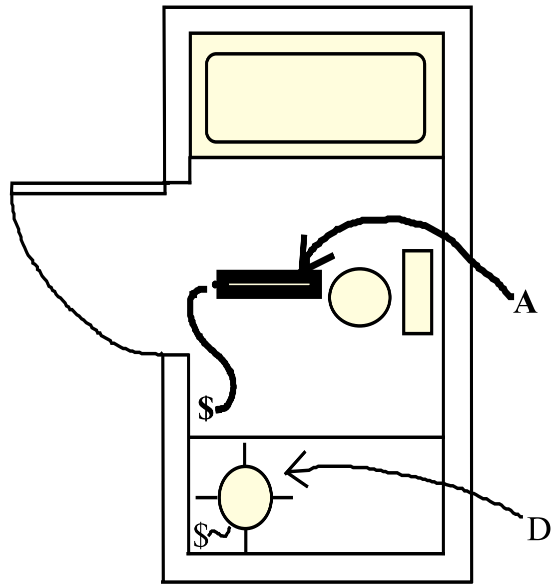
All of "A" or "C" must be fluorescent
If "C" then "C" must be the most accessible switch

This alternative is not sufficient if 'A' is incandescent and 'C' does not provide sufficient illumination for the insides of cabinets.

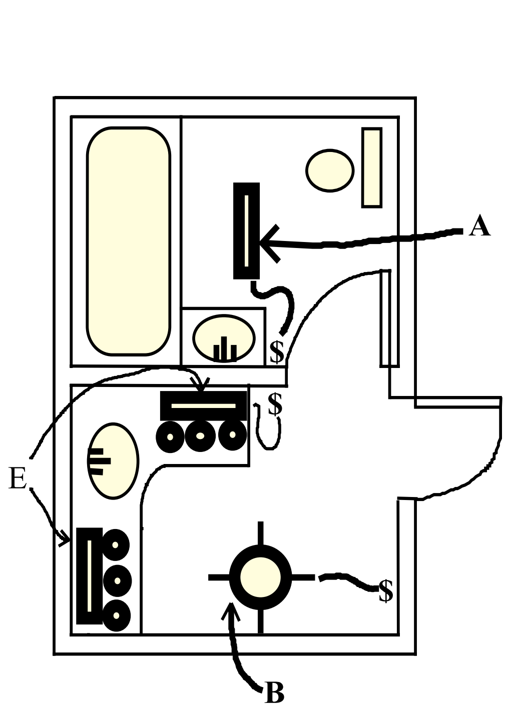
Figure 5-12– Residential and Hotel/Motel Guestroom (Bathroom Lighting Examples)



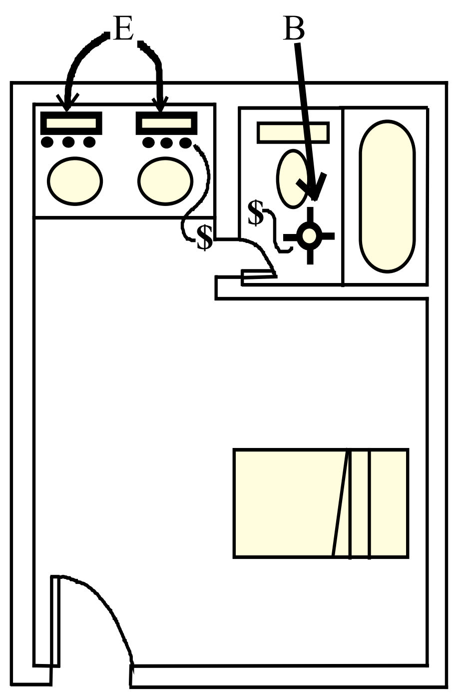
"A" must be fluorescent



"A" must be fluorescent
"D" can be incandescent



"A", "B" or “E” must be fluorescent



"B" or "E" must be fluorescent

General (§130(b)3&4)

Luminaires installed to meet the 40 lumens per watt requirements cannot contain medium base incandescent lamp sockets, and must be on separate switches from incandescent lighting.

All incandescent lighting fixtures recessed into insulated ceilings must be approved for zero-clearance insulation cover (I.C.) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials (ICBO).

Recessed lighting fixtures left uninsulated significantly increases the heat loss and heat gain through the roof/ceiling area.

The designer has the option to exempt as many as 10 percent (by number) of the guest rooms in a hotel/motel from this requirement. This may be desirable for special consideration rooms, such as executive suites, penthouses, etc.

Exterior Lighting (§130(c))

A minimum efficacy requirement of 60 lumens per watt, determined by dividing the rated initial lamp lumens by the rated lamp watts, applies to permanently installed exterior lighting attached to or powered by the electrical service contained in buildings with conditioned space(s). This does not apply if the fixtures are controlled by motion sensors or employ lamps that are rated at or below 100 watts.

Fixtures exempt from the minimum efficacy/motion sensor requirement include:

Lighting required by a health or life safety statue, ordinance, or regulation, including but not limited to emergency lighting;

Lighting that is integral to advertising signage. (Integral lighting is lighting that is internally part of the sign, or lighting that is the sign, such as neon or Light Emitting Diode (LED) signs);

Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electric Code;

Searchlights and theme park lighting;

Temporary (or periodically used) lighting for outdoor theatrical use

5.2.2 Prescriptive Approach

The prescriptive approach for lighting involves a comparison of the building's Allowed Lighting Power with its Actual Lighting Power (as adjusted). This section describes the procedures and methods for using the prescriptive approach to comply with the *Standards*. It incorporates common energy efficiency measures that are easily integrated into building designs.

To determine the Allowed Lighting Power using the prescriptive approach, there are three methods: the Complete Building, the Area Category and the Tailored Method.

Note: The Complete Building Method can be used for tenant improvements where at least 90 percent of the permitted space is one Type of Use (which may include the following areas if they serve as support for the primary Type of Use: lobbies, corridors, restrooms and storage closets).

A. Allowed Lighting Power - Complete Building Method (§146(b)1)

The Complete Building Method (see Figure 5-13) of determining the Allowed Lighting Power can only be applied when all areas in the entire building are complete (i.e. lighting will be installed throughout the entire building under the permit for which the Title 24 compliance is prepared). The building must consist of one Type of Use for a minimum of 90 percent of the conditioned floor area (in determining the area of the primary Type of

Use, include the following areas if they serve as support for the primary Type of Use: lobbies, corridors, restrooms and storage closets). There cannot be any unfinished areas. To determine the Allowed Lighting Power, multiply the complete building conditioned floor area times the lighting power density for the specific building type, as found in Table 5-3.

Note: High-rise residential and hotel/motel buildings cannot use the Complete Building Method.

Table 5-3 - Complete Building Method Lighting Power Density Values

Type of Use Allowed Lighting Power	W/ft^2
General commercial and industrial work buildings:	
High bay	1.2
Low bay	1.0
Grocery stores	1.5
Industrial and commercial storage buildings	0.7
Medical buildings and clinics	1.2
Office buildings	1.2*
Religious facilities, and auditorium	1.8
Convention centers	1.4
Restaurants	1.2
Retail and wholesale stores	1.7
Schools	1.4
Theaters	1.3
All others	0.6

*The *Standards* make it clear that office lighting power includes portable task lighting. In open offices greater than 250ft^2, the standard requires that 0.2 W/ft^2 be assumed for task lighting, even if no task lighting is shown on the plans and specifications (unless the lighting design conclusively establishes that no portable lighting is required- see 5.2.4B).

Example 5-10– Complete Building Method

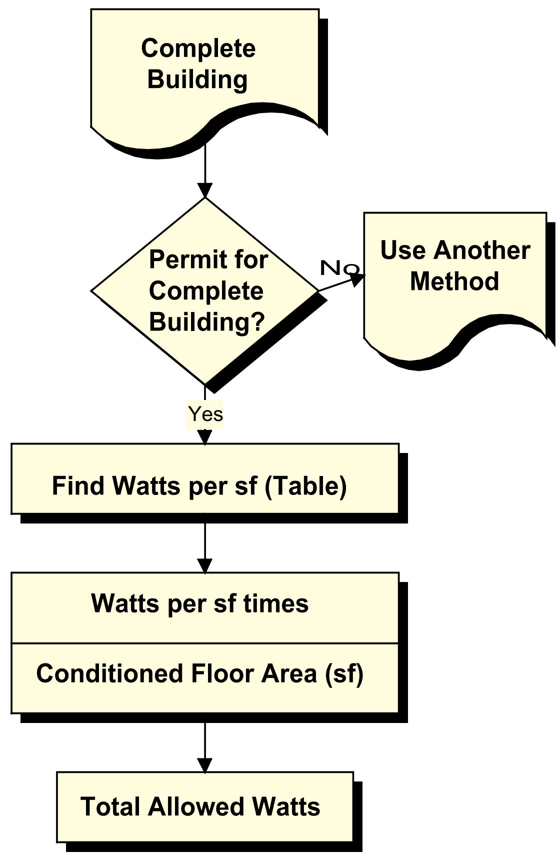
Question

A 10,000 ft² Medical Clinic Building is to be built. What is its Allowed Lighting Power under the Complete Building Approach?

Answer

From Table 5-3, Medical Buildings and Clinics are allowed 1.2 watts per square foot. The Allowed Lighting Power is 10,000 x 1.2 = 12,000 watts.

Figure 5-13– Complete Building Method Flowchart



Exception to §146(b)2: The tailored method (§146(b)3) may be used for up to 10 percent of the floor area of a building that is otherwise using the area category method. The two lighting methods cannot be used for the same floor area. The floor area for calculations based on the tailored method must be subtracted from the floor area for the remainder of the building lighting calculations. Trade offs of lighting between the two methods is not allowed.

B. Allowed Lighting Power - Area Category Method (§146(b)2)

The Area Category Method is more flexible than the Complete Building Method because it can be used for multiple tenants or partially completed buildings. Areas not covered by the current permit are ignored. When the lighting in these areas is completed later under a new permit the applicant may show compliance with any of the lighting options except the Complete Building Method.

The Area Category Method shown in flowchart form in Figure 5-14 divides a building into primary function areas. Each function area is defined under Occupancy Type in *Standards* §101(see Section 5.1.1B). When using this method, each function area in the building must be included as a separate area. Boundaries between primary function areas may or may not consist of walls or partitions. For example, kitchen and dining areas within a fast food restaurant may or may not be separated by walls. Also, it is not necessary to separate aisles or entries within primary function areas. Figure 5-15 shows a function area that has interior, nonbounding partitions (dotted) and bounding partitions (solid). The area is calculated by multiplying the width times the depth, as measured from the center of the bounding partitions.

The Allowed Lighting Power is determined by multiplying the area of each function times the lighting power density for that function. The Total Allowed Watts is the summation of the Allowed Lighting Power for each area covered by the permit application.

Figure 5-14– Area Category Method Flowchart

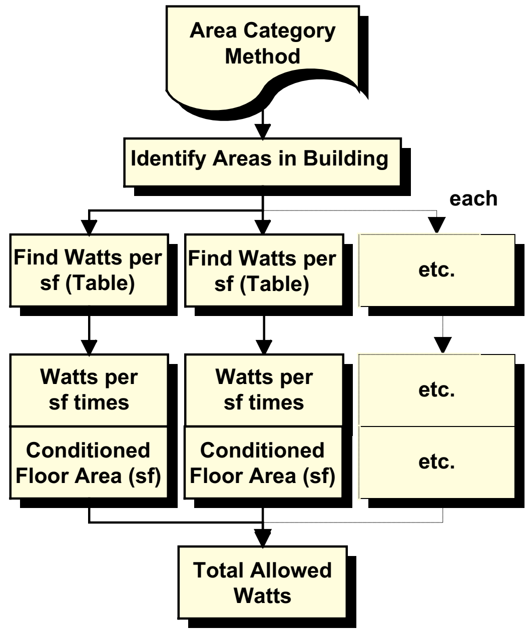
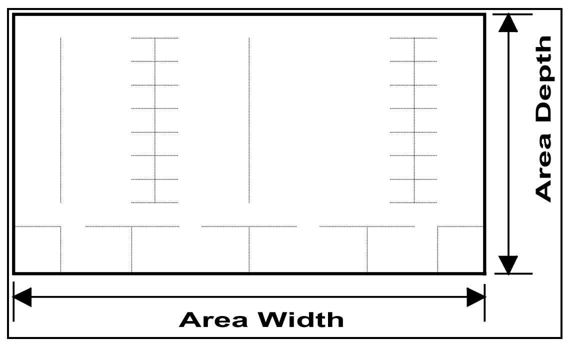


Figure 5-15– Calculating Lighting Area



Transferring lighting wattage from one area to another is acceptable only for areas for which lighting plans are being submitted and lighting is being installed as part of the same approved permit. The Primary Function area allotments are found in Table 5-4.

Table 5-4 - Area Category Method LPD Values

Primary Function	Allowed Lighting Power	Primary Function	Allowed Lighting Power
All Other	0.6	Library	
Auditorium[2]	2.0[1]	Reading Areas	1.2
Auto Repair	1.2	Stacks	1.5
Banks/Financial Institutions[2]	1.4	Lobbies:	
Classrooms/Training	1.6	Hotel Lobby	1.7[1]
Commercial Storage	0.6	Main Entry Lobby	1.5[1]
Conference Centers[2]	1.5[1]	Reception/Waiting	1.1[1]
Convention Centers[2]	1.5[1]	Locker Room	0.8
Corridors	0.6	Lounge/Recreation	1.1
Dining	1.1[1]	Malls, Arcades, and Atria	1.2[1]
Dressing Room (Gymnasium)	0.9	Mechanical Rooms	0.7
Electrical Rooms	0.7	Medical and Clinical Care[2]	1.4
		Meeting Centers	1.5[1]
Exhibit, Museum	2.0	Multipurpose Centers[2]	1.5[1]
General Commercial Work		Museum Exhibit	2.0
High Bay	1.2	Office	1.3*
Low Bay	1.0	Precision Commercial Work	1.5
General Industrial Work		Precision Industrial Work	1.5
High Bay	1.2	Religious Worship	2.1[1]
Low Bay	1.0	Restrooms	0.6
Grocery Stores[2]	1.6	Retail Sales	2.0
Gymnasium/Exercise Center	1.0	Stairs	0.6
Hotel Function Area	2.2[1]	Support Areas	0.6
Industrial Storage	0.6	Theaters	
Kitchen/ Food Preparation	1.7	Motion Picture	0.9
Laundry	0.9	Performance	1.4[1]
Lecture	1.6[1]	Vocational Room	1.6
		Wholesale Showrooms	2.0

*The *Standards* make it clear that office lighting power includes portable task lighting. In open offices greater than 250ft^2, the standard requires that 0.2 W/ft^2 be assumed for task lighting, even if no task lighting is shown on the plans and specifications (unless the lighting design conclusively establishes that no portable lighting is required- see 5.2.4B).

1. The smallest of the following values may be added to the allowed lighting power listed in Table 5-4, for ornamental chandeliers and sconces that are switched or dimmed on circuits different from the circuits for general lighting:

a. 20 watts per cubic foot times the volume of the chandelier or sconce; or

b. 1 watt per square foot times the area of the task space that the chandelier or sconce is in; or

c. Actual design wattage of the chandelier or sconce.

2. The LPD values from Table 5-4 for these occupancies are not whole building values for the entire occupancy. These values may only be applied to spaces within these occupancies not covered by other Primary Function Areas. For example - offices, corridors, restrooms, and mechanical rooms within these occupancies must be separated out and assigned appropriate LPD values from Table 5-4.

Example 5-11– Area Category Method

Question

A small bank building has the following area distribution:

Corridors	800 ft^2
Main Entry Lobby	200 ft^2
Banking	1200 ft^2
Manager's Office	200 ft^2

What is the Allowed Lighting Power for this building under the Area Category Method?

Answer

The following Lighting Power Densities apply (from Table 5-4):

Space	LPD	Area	
Corridors	0.6 W	800 ft^2	480
Main Entry	1.5 W	200 ft^2	300
Banking	1.4 W	1200 ft^2	1680
Manager's Office	1.3 W	200 ft^2	260
Total			2720 W

Banking in this example is assumed to include all the spaces in which financial transactions for the public are taking place (note that under the Area Category Method, the LPD for Bank applies to teller space only). The Allowed Lighting Power for this building is 2720 W.

Chandeliers and Sconces §146(b)3H

Certain function areas use decorative lighting in the form of ornamental chandeliers or sconces. Areas shown in Table 5-4, with a reference to Footnote 1, qualify for an additional lighting allotment that may be added to the Allowed Lighting Power under the Area Category Method. Ornamental chandeliers are ceiling-mounted or suspended decorative luminaires that use glass crystal, ornamental metal or other decorative materials. Sconces are wall mounted decorative lighting fixtures.

Supplemental watts can be added to the Allowed Lighting Power to accommodate the decorative portion of the fixture.

Example 5-12– Area Category Method

Question

A 10,000 square foot multi-use building is to be built consisting of:

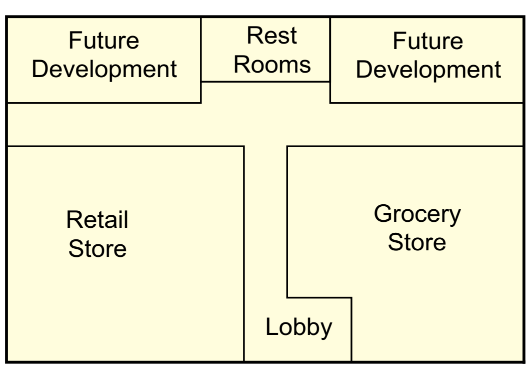
A) 500 square foot main entry lobby

B) 2,000 square foot corridors and restroom

C) 3,000 square foot grocery store

D) 2,500 square foot retail, and

E) 2,000 square foot future development



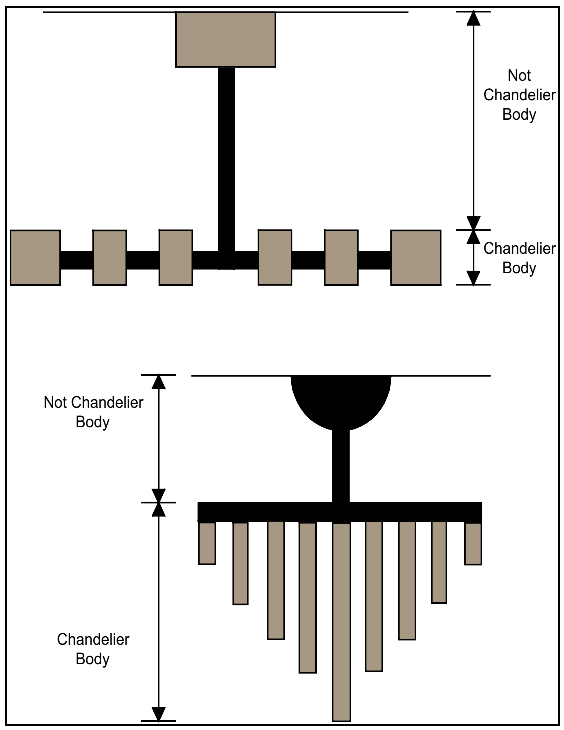
What is the Allowed Lighting Power under the Area Category Method?

Answer

A)	Main Entry	1.5 w/ft²	500sf	750W
B)	Corridors and			
	Restrooms	0.6 w/ft²	2,000sf 1,200W	
C)	Grocery Store	1.6 w/ft²	3,000sf 4,800W	
D)	Retail Store	2.0 w/ft²	2,500sf 5,000W	
	TOTAL	8,000 ft²	11,750W	

with 2000 square feet for future development.

Figure 5-16– Chandelier Dimensions



Example 5-13– Chandelier Wattage Allowance

Question

What is the wattage allowance for a 10 cubic foot chandelier with 5-50 watt lamps in a 300 square foot entry lobby?

Answer

The wattage based on cubic feet is 10 cf x 20 w/cf = 200 watts

The wattage based on the task space is 1 w/ft² x 300 ft² = 300 watts

The wattage based on actual design watts is 250 watts.

The wattage allowance for the chandelier is the smallest of the three values, or 200 watts.

C. Allowed Lighting Power - Tailored Method §146(b)3)

The maximum Allowed Lighting Power is determined for each space or activity when the Tailored Method is used. The difference between the Tailored Method and the Area Category Method, is that the Tailored Method takes into account each task activity in each enclosed space or task area as the basis for determining the lighting power allotment (as opposed to functional areas, which may have several different tasks).

Because the Tailored Method is based on task activities, this method requires the most detail on the plans, and in some cases, requires documentation of the actual lighting tasks. The Tailored Method may allow more lighting power than the other two methods.

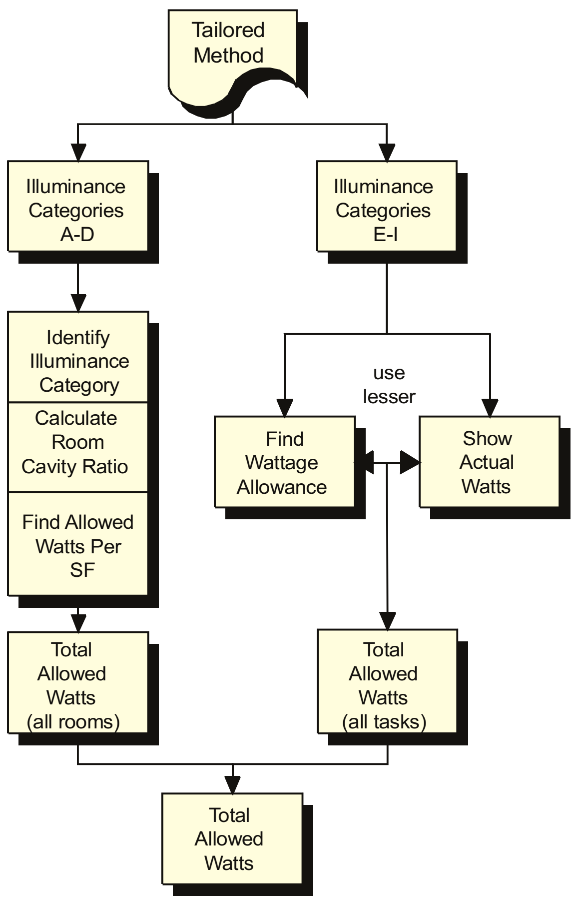
The task allotments are defined in terms of the illuminance category for each task. The Illuminating Engineering Society (IES) uses illuminance category and foot-candle levels for determining design lighting levels. Because the task allotments are based on the same categories as the IES design lighting levels, this method allows designers to translate their design parameters directly into allowed lighting power levels.

The *Standards* make it clear that office lighting power includes portable task lighting. In open offices greater than 250ft^2, the standard requires that 0.2 W/ft^2 be assumed for task lighting, even if no task lighting is shown on the plans and specifications (unless the lighting design conclusively establishes that no portable lighting is required- see 5.2.4B).

Note: In many buildings the Tailored Method may actually result in less allowed lighting power than other methods. Larger allowances generally result from special lighting needs in a substantial portion of the building or from control credits.

The Tailored Method uses the process shown in Figure 5-17 for determining the Allowed Lighting Power.

Figure 5-17– Tailored Method Flowchart



Determining Illuminance Categories (§146(b)3A)

The first step in identifying the Allowed Lighting Power when using the Tailored Method is to determine the illuminance category for each task. Illuminance categories are determined according to the task activity that will be performed. For each task, the appropriate illuminance category is found in Table B-10 (Appendix B), or in tables and procedures found in the IES Handbook, Applications Volume, 1987. Selection of each illumination category must be supported by a justification on the plans.

The *Energy Commission* has simplified the selection of illuminance categories for some specific types of tasks. These are listed in Table 5-6.

Illuminance categories A, B, C, and D are used for general lighting, and may be assigned within spaces without detailed supporting documentation. In fact, these categories may be used for allotments in spaces where the actual task areas are not yet defined based upon general plan designations such as: office, hallway, or rest room.

Selection of illuminance categories E through I require specific identification of the task area, as well as of the luminaires and wattages assigned to it. If it is determined from Table 5-6 or from Appendix B, Table B-10 that one of these categories applies to a particular task, then the next step is to determine the area of the task (see below).

In cases where the office lighting needs cannot be met using category D, private offices and workspaces receive a special lighting allotment based on the ANSI/IES RP-1, Office Lighting American National Standard Practice. These spaces are defined in §101 as follows:

Private Office or Work Area is an office bounded by 30-inch or higher partitions and is no more than 200 square feet.

Table 5-5 - Illuminance Categories for Tasks

Illuminance Categories for Tasks

Task Area	***Illuminance Category***
Churches:	
Altar, Ark, Reredos	*E*
Choir and Chancel	*D*
Main Worship Area	*D*
Pulpit, Rostrum	*E*
Dining	*D*
Office	*D**
Public Area Displays	*G*
Sales Feature Displays	*G*
All Others	*IES Handbook*

**Special criteria if higher illuminance category needed (see text above).*

Note: All categories E and higher require consideration. See explanatory sections on following pages.

Category E can only be applied in offices which have visually difficult tasks requiring extra illumination, and can only be used for up to 50 percent of the area of the office. The remainder of the office is calculated using 0.4 w/ft².

The criteria for determining if a task is visually difficult is based on the duration of time spent on the more difficult task. This means that the illuminance category for visual task requirements shall not be based upon an incidental task, or combination of tasks which specify the use of a given illuminance category when the incidence of these tasks totals less than two hours per working day.

A number of tasks may be visually difficult because their quality is poor. If the task quality can be improved, such tasks are not permitted to be the basis of an increased power allotment. This is especially applicable to category E tasks. The ANSI/IES RP- list the following as poor quality office tasks that are capable of being improved, and thus, do not qualify for the higher illuminance categories:

- Ditto copy, Thermal copy, poor copy and thermal printer
- Xerography, third generation and greater
- Impact printer, second carbon or later
- Typed print, second carbon or later
- Printing—6 point type
- Handwritten carbon copies
- Handwritten pencil harder than No. 2

The reason these tasks are not allowed as the basis for higher lighting levels is because efficient practices are generally available which will eliminate the higher lighting need by substituting better quality tasks. Examples of these good quality alternatives are:

- Mimeograph and xerography copy
- Impact printers with good ribbon
- Typed originals in 8 point and larger type
- Handwritten originals in No. 2 pencil or pen

As a general rule, it is unusual for office environments other than graphic, architectural, or engineering design studios (or similar types of occupancy) to need Category E or higher illuminance levels. Applicants must provide an affidavit signed by the building owner/user that provides substantial justification for such visual “needs” and building officials should question extensive use of high level lighting requirements for common office spaces.

Example 5-14–Office Task Duration

Question

Can illuminance category "E" be used in an office because every office worker is expected to read fax transmittals and use a phone book?

Answer

This activity would not normally meet the test of two hours duration to allow use of Category “E”. However, a special business that involved reading phone books on a regular basis for most of the day could be documented and allowed the higher lighting category.

Determining LPD Values

After the illuminance category is determined, the next step is to find the lighting power density (LPD), in watts per square foot (w/ft^2), for each category. This depends on the illuminance category, and also on the room cavity ratio (see below) for categories A through E, Table 5-7, and upon throw distance for categories F through I, Table 5-8.

Room Cavity Ratio (RCR)

The lighting level in a room is affected by the amount of light its fixtures provide and by the configuration of the room, expressed as the Room Cavity Ratio (RCR) (definition in §101). Since lighting fixtures are not as effective in rooms with high RCRs, the *Standards* allow a greater LPD to compensate for this effect in rooms with high RCRs.

For the Tailored Method, the maximum adjusted LPD assigned to illuminance categories A through E depends on the RCR of the space.

The RCR is based on the entire space bounded by floor to ceiling partitions. If a task area within a larger space is not bounded by floor to ceiling partitions, the RCR of the entire space must be used for the task area.

The RCR is calculated from one of the following formulas:

Rectangular Shaped Rooms

$$RCR = \frac{5\ \ H\ \ \ L\ \ \ W}{Area}$$

Where:

RCR = The room cavity ratio.

H = The room cavity height, vertical distance measured from the work plane to the center line of the lighting fixture.

L = The room length.

W = The room width.

Non-rectangular Shaped Rooms

$$RCR = \frac{2.5\ \ H\ \ \ P}{Area}$$

Where:

RCR = The room cavity ratio.

H = The room cavity height (see equation above).

A = The room area.

P = The room perimeter.

It is not necessary to calculate RCR values for rooms with an RCR less than 3.5. Rooms with RCRs higher than 3.5 are allowed higher LPDs under the Tailored Method (see Table 5-7). Table 5-6 gives typical RCR values calculated for rooms with the task surface at desk height (2.5 ft above the floor). This table is useful in assessing whether or not a room is likely to have an RCR greater than 3.5.

The LTG-5 may be used to calculate RCR values greater than or equal to 3.5. After the RCR is determined, the LPD can be found.

Table 5-6 - Typical RCRs for Flush/Recessed Luminaires (Task height 2.5 ft above floor)

Room Length (ft)	Room Width (ft)				
	8	**12**	**16**	**20**	**24**
5	8.9	7.8	7.2	6.9	6.6
8	6.9	5.7	5.2	4.8	4.6
12	. . .	4.6	4.0	3.7	3.5
16	. . .	. . .	3.4	3.1	3.0
20	. . .	. . .	. . .	2.8	2.5
24	. . .	. . .	. . .	. . .	2.3
Room Cavity Height = 5.5 ft (eight feet from floor to luminaire)					
5	12.2	10.6	9.8	9.4	9.1
8	9.4	7.8	7.0	6.6	6.3
12	. . .	6.3	5.5	5.0	4.7
16	. . .	. . .	4.7	4.2	3.9
20	. . .	. . .	. . .	3.8	3.4
24	. . .	. . .	. . .	. . .	3.1
Room Cavity Height = 7.5 ft (ten feet from floor to luminaire)					

Example 5-15– RCR Calculation

Question

A private office is 12 ft wide, by 12 ft long, by 9 ft high. The lighting system uses recessed ceiling fixtures. The task surface is at desk height (2.5 ft above the floor). What is the room cavity ratio?

Answer

The room cavity height is the distance from the ceiling (center line of luminaires) to the task surface (desk height). This is 9 ft – 2.5 ft = 6.5 ft.

RCR = [5 x H x (L + W)] / Area

RCR = [5 x 6.5 x (12 + 12)] / (12 x 12) = 5.42

LPD for Categories A, B, C, and D

The LPD allowed for each illuminance category is determined using the room cavity ratio (RCR) and Table 5-7, which show the LPD's for illuminance categories A, B, C, D (and E). Document on LTG-4, Part 1 of 3. To calculate RCR, see above formulas.

Table 5-7- Illuminance Categories A – E

Lighting Power Density Illuminance Categories A-E			
Illuminance Catagories	Room Cavity Ratio		
	0 to < 3.5	>=3.5 to < 7	>=7
A	0.2	0.3	0.4
B	0.4	0.5	0.7
C	0.6	0.7	1.1
D	0.99	1.24	1.49
E	2.31	2.97	3.88

Note: Interpolation is not allowed.

Table 5-8 - Illuminance Categories F - I

Lighting Power Density Illuminance Categories F-I		
Illuminance Category	Task Area <= 2 sf or Throw Distance > 8 ft.	Task area > 2 sf and Throw Distance <= 8 ft.
F	9.0	4.5
G	23.4	11.7
H	56.7	29.7
I	117.0	58.5

LPD for Categories E, F, G, H, and I.

The allowed lighting power density for illuminance categories E, F, G, H and I are limited to either the value obtained in Tables 5-7 or 5-8, or the actual watts of design lighting, whichever is less. The lighting must be assigned to the task area. Adjacent non-task areas must be assigned an illuminance category between A and D.

Illuminance category E is different from categories F-I because it depends upon the RCR rather than the task area or the throw distance. In all other respects, however, these categories are treated alike. Document on LTG-4, Part 2 of 3.

The task area for each category must be determined by individual task and documented on the plans. See below for the rules and special cases for *Determining Area of a Task*.

Special Cases: General Lighting

The Allowed Lighting Power Density for library and warehouse stack type installations is based on illuminance category C for bulky item warehousing and D for library shelving. The RCR for stacks is assumed to be "7," and the appropriate LPD is found in Table 5-7. See below for an additional discussion of the determination of stack lighting area.

Neither the gross sales floor area nor the gross sales wall area for retail stores are assigned illuminance categories. Instead, these areas are assigned watts per square foot allowances.

Gross sales floor area is assigned an LPD of 2.0 watts per square foot, of associated retail area, regardless of the RCR (§146(b)3.D and E).

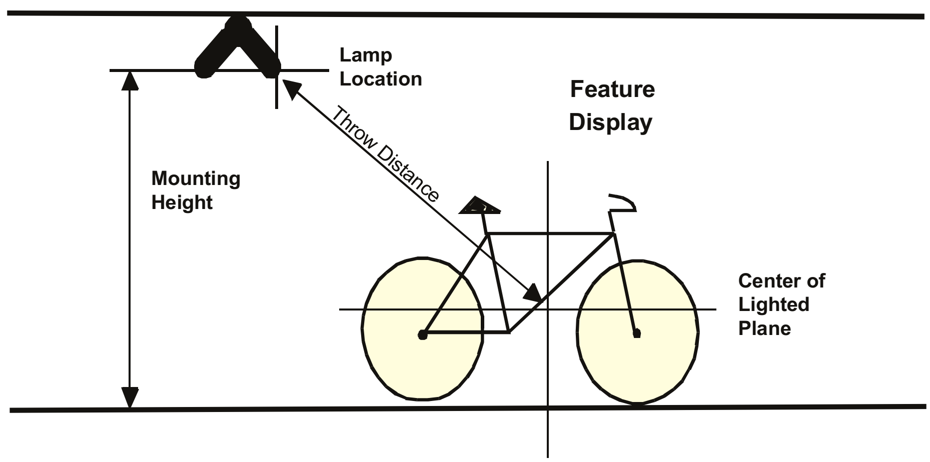
Gross sales wall area is limited to either 2.0 watts per square foot of actual wall area display, or the actual watts of design lighting, whichever is less (§146(b)3.D and G).

See definition of areas below in *Determining Area of a Task.*

Throw Distance. For illuminance categories F-I, the LPD allowance is higher when the throw distance from the lamp location to the display is greater than eight feet. See Figure 5-18 for an illustration of how throw distance is calculated. When there are tasks illuminated by lamps with different throw distances, the shortest throw distance is used to determine the LPD allowance from Table 5-8. When track lighting is used and no fixtures are shown on the plans, the throw distance is measured perpendicular to the track from the point nearest the display.

Mounting Height. When the special circumstances of a space require that luminaires for tasks in illuminance categories A-D or E-I be mounted at a height more than 15 feet from the floor (see Figure 5-18), additional lighting power is permitted. Table 5-9 lists mounting height adjustments for various mounting heights. The appropriate multiplier is applied to the assigned LPD value from Table 5-7 or 5-8. The building department may request justification for mounting heights greater than 15 feet.

Figure 5-18– Throw Distances and Mounting Heights



When there is more than one mounting height condition, they should be separated into different task areas for purposes of applying the mounting height adjustments. The boundaries of these separate areas should be clearly shown on the plans, and the mounting height in each should also be shown with a section diagram.

Determining Area of a Task

In order to determine the Allowed Lighting Power, the task areas need to be identified. For illuminance categories A, B, C and D, the task areas are the areas of each task space that has a separate illuminance requirement. The area of each task space is determined by measuring the dimensions from inside the bounding partitions. Figure 5-19 shows a task area that has interior partitions (dotted) and bounding partitions (solid). The area is calculated by multiplying the width times the depth, as measured from the inside of the bounding partitions. The floor area occupied by the interior partitions is not included in the floor area of the function area.

Following are special rules for determining task areas in specific areas.

Office Lighting

When illuminance category E is used for private offices or workspaces, it must not be applied to more than 50 percent of the space, and the remainder of the area is allotted a 0.4 W/ft² lighting power density. When Category E lighting is used, the areas must be clearly identified on the plans.

Table 5-9 - Mounting Height Adjustments

Required Mounting Height	Multiplier
15 feet	1.15
16 feet	1.21
17 feet	1.47
18 feet	1.65
19 feet	1.84
20 feet or more	2.04

Example 5-16– Private Office

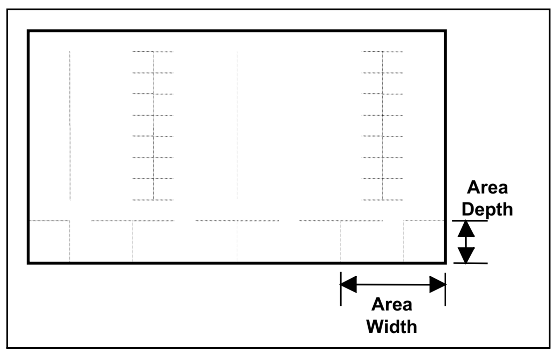
Question

The private office in Example 5-12 (RCR Calculation) is to comply under illuminance Category E. What is the Allowed Lighting Power?

Answer

The RCR is 5.4 and the area of the office is 144 ft² Since 50% of the private office is allowed task E, 72 ft² times 2.97 W/ft² (RCR of 5.4 from Table 5-7) is 213.84 watts. The remaining private office space is calculated at 0.4 W/ft² times 72 ft² for a subtotal of 28.8 watts. The total Allowed Lighting Power for this space is 28.8 watts plus 213.84 watts for a total of 242.64 watts.

Figure 5-19– Calculating the Task Area



Retail and Special Display Lighting

The Tailored Method includes special provisions for retail and display lighting. The following definitions are from §101; they are necessary to determine how the retail and display lighting provisions apply.

Display Lighting *is lighting confined to the area of a display that provides a higher level of illuminance than the level of surrounding ambient illuminance.*

Display, Public Areas *are areas for the display of artwork, theme displays, and architectural surfaces in dining and other areas of public access, excluding restrooms and separate banquet rooms.* A lighting level of Category G can be applied to these special features. This allowance cannot be used for retail applications where the highlighted feature is for sale.

The public area display is the wall or floor area used for the display of artwork, theme displays, and architectural surfaces. They are limited to areas of public access, excluding restrooms and separate banquet rooms. The public area display is limited to 10 percent of the area on the plane of the display, available for each display. A space may contain both wall and floor display. Each display area must be calculated separately. These wall or floor areas are determined in a similar manner to gross sales wall or floor areas.

Display, Sales Feature *is an item or items that requires special highlighting to visually attract attention and that is visually set apart from the surrounding area.*

Display, Sales Feature Floor *is a feature display in a retail store, wholesale store, or showroom that requires display lighting.* The sales feature floor display area is confined to the actual area of display. For purposes of calculating the lighting power allowance (which is based on a Category G lighting level), this area cannot exceed 10 percent of the Gross Sales Floor Area, unless the stores gross sale area is smaller than 800 square feet in area, in which case it is permitted a Sales Feature Floor Display allowance of 1000 watts. The display areas should be clearly identified on the plans.

Display, Sales Feature Wall *are the wall display areas, in a retail or wholesale space, that are in the vertical plane of permanent walls or partitions, and that are open shelving feature displays or faces of internally illuminated transparent feature display cases within the Gross Sales Wall Area.* For purposes of calculating the Allowed Lighting Power, the Sales Feature Wall Display area is limited to 10 percent of the Gross Sales Wall Area at a Category G lighting level. Additionally, the areas should be clearly identified on the plans.

Gross Sales Floor Area *is the total area (in square feet) of a retail store floor space that is (1) used for the display and sale of merchandise, or (2) associated with that function, including, but not limited to, sales transactions areas, fitting rooms and circulation areas and entry areas within the space used for display and sale.* (See discussion of allotted LPD for Gross Sales Floor Area above at Special Cases: General Lighting.).

Gross Sales Wall Area *is the area (in square feet) of the inside of exterior walls and permanent full height interior partitions within the gross sales floor area of a retail store that is used for the presentation of merchandise for sale, less the area of openings, doors, windows, baseboards, wainscots, mechanical or structural elements, and other obstructions preventing the use of the area for the presentation of merchandise* (see Figure 5-20). The walls must be associated with the Gross Sales Floor Area. (See discussion of allotted LPD for Gross Sales Wall area above at Special Cases: General Lighting).

Very Valuable Merchandise *is rare or precious objects, including, but not limited to, jewelry, coins, small art objects, crystal, china, ceramics, or silver, the selling of which involves customer inspection of very fine detail from outside of a locked case.*

The Allowed Lighting Power for very valuable merchandise is 20 watts/ft^2 of lighted case top, or actual watts, whichever is smaller. Floor display cases, that contain jewelry and other valuable merchandise are allowed this allotment for each square foot of lighted display case counter top. To qualify for this allotment, illumination for the valuable merchandise must be provided from above the display case.

Detailed documentation should be provided on the plans that shows the placement of display cases, specific dimensions, and details of proposed lighting systems.

Example 5-17– Allowed Lighting Power, Tailored Method

Question

A 5,500 square feet (ft²) retail store has:

a. 5,000 square feet of gross sales floor area

b. 200 ft² of restrooms with a RCR of 6.0

c. 300 ft² of corridors with a RCR of 6.5

d. 150 ft² of actual sales feature floor display area

e. 100 ft² of very valuable merchandize case top with 1,200 watts of actual lighting

f. 1,500 ft² of actual gross sales wall area used for merchandize display

g. 100 ft² of actual sales feature wall display area

What is the allowed lighting wattage in this store using the Tailored Method?

Answer

a. 5,000 ft² x 2.0 w/ft² of gross sales floor area = 10,000 watts

b. From IESNA Handbook, restrooms are at illuminance category C. From Table 5-6, at illuminance category C and RCR of 6.0, the LPD is 0.7 w/ft², therefore, the allowed power is 200 ft² x 0.7 w/ft² = 140 watts

c. From IESNA Handbook, corridors are at illuminance category C. From Table 5-6, at illuminance category C and RCR of 6.5, the LPD is 0.7 w/ft², therefore, the allowed power is 300 ft² x 0.7 w/ft² = 210 watts

d. Maximum sales feature floor display area is 10% of gross sales floor area, which is 5,000 ft² x 10% = 500 ft², which is greater than the actual area of 150 ft². From Table 5-7, at illuminance category G and task area greater than 2 ft², the allowed LPD is 11.7 w/ft². Therefore, the allowed wattage is 150 ft² x 11.7 w/ft² = 1,755 watts

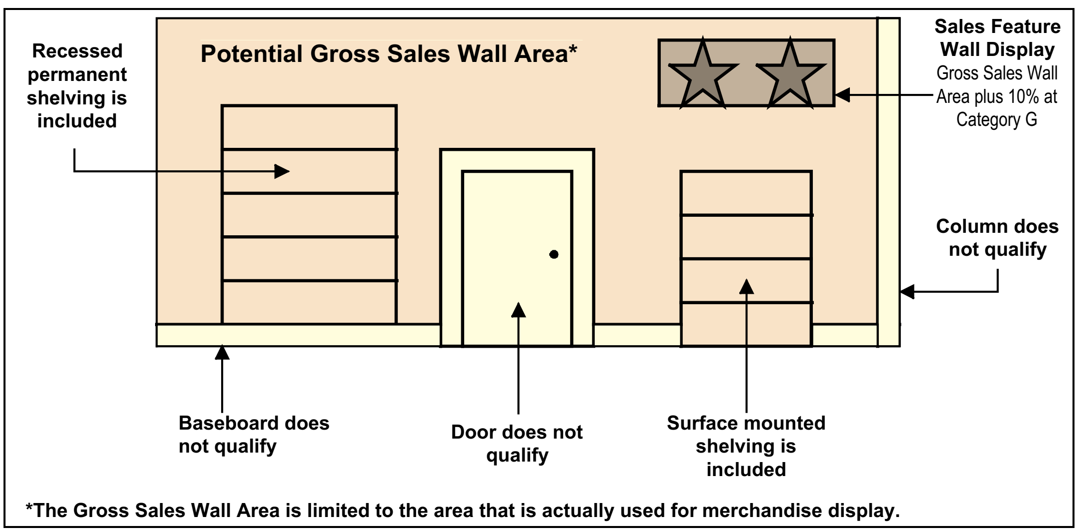
e. The allowed wattage for very valuable merchandize case top is the lower of actual watts or 20 w/ft². The calculated watts are 100 ft² x 20 w/ft² = 2,000 watts, therefore, the allowed power is the actual 1,200 watts.

f. 1,500 ft² x 2 w/ft² of actual gross sales wall area = 3,000 watts

g. Similar to (d) above, the allowed wattage for sales feature wall display area is 100 ft² x 11.7 w/ft² = 1,170 watts

Therefore, the total allowed lighting wattage is 10,000 + 140 + 210 + 1,755 + 1,200 + 3,000 + 1,170 = 17,475 watts. Please note that in Tailored Method, the allowed wattage for each lighting task activity is of the "use it or lose it" kind, which prohibits tradeoffs between different tasks.

Figure 5-20– Gross Sales Wall Area



Library and Warehouse Stacks

A special situation occurs when illuminating stacks of shelves in libraries, warehouses, and similar spaces. In this situation, the lighting requirements are to illuminate the vertical stack rather than the horizontal floor area (see Figure 5-21). In stack areas, as discussed above, the RCR is assumed to be greater than seven. The non-stack areas are treated normally.

Example 5-18– Stack Lighting RCR

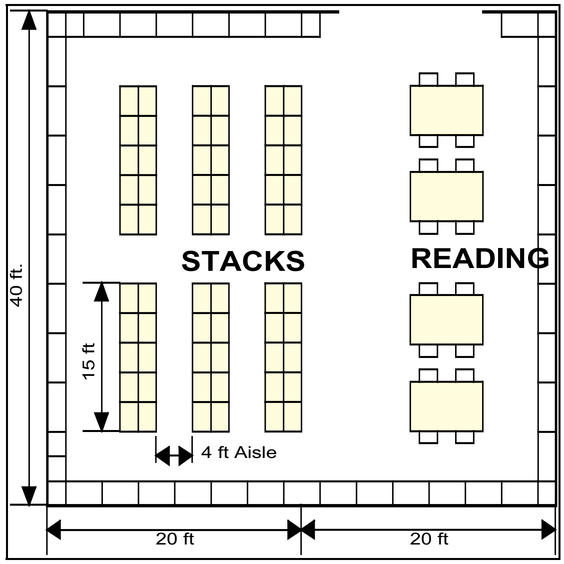
Question

How is the RCR determined for the library reading room/stack area shown in Figure 5-21?

Answer

A RCR value of 7 may be assumed for the stack area. The reading area RCR is calculated based on the reading area room dimensions (20 ft x 40 ft) and on the room cavity height.

Figure 5-21– RCR for Stack Lighting (see Example 5-14)



Other Task Areas

Task areas not mentioned in the previous discussion are determined based on the actual area of each task. These other task areas must be identified on the plans submitted for permit.

Determining Allowed Watts

After the LPD and task area assigned to each space or task is established, the allowed watts may be calculated. There are two cases:
For illuminance categories A through D and for the Gross Sales Floor Area, the allowed watts are calculated simply by multiplying the LPD (watts/ft²) by the area of the space (ft²).

For illuminance categories E through I, Gross Sales Wall Areas and feature displays, the allowed watts are the lesser of:

a) the LPD (watts/ft²) multiplied by the area of the task (ft²) to obtain allotted watts, and

b) the design watts of the luminaires assigned to the task.

The sum of the allowed watts for all spaces and tasks is the building Allowed Lighting Power, in watts, as determined by the Tailored Method.

Allocation Restrictions of Task Lighting

When using the Tailored Method, the determination of task lighting is based on need. Therefore, lighting plans must be submitted that show the actual task lighting application. Task lighting allotments from walls, floors or special applications cannot be traded off for use as general lighting.

D. Simplification for Tenant Spaces

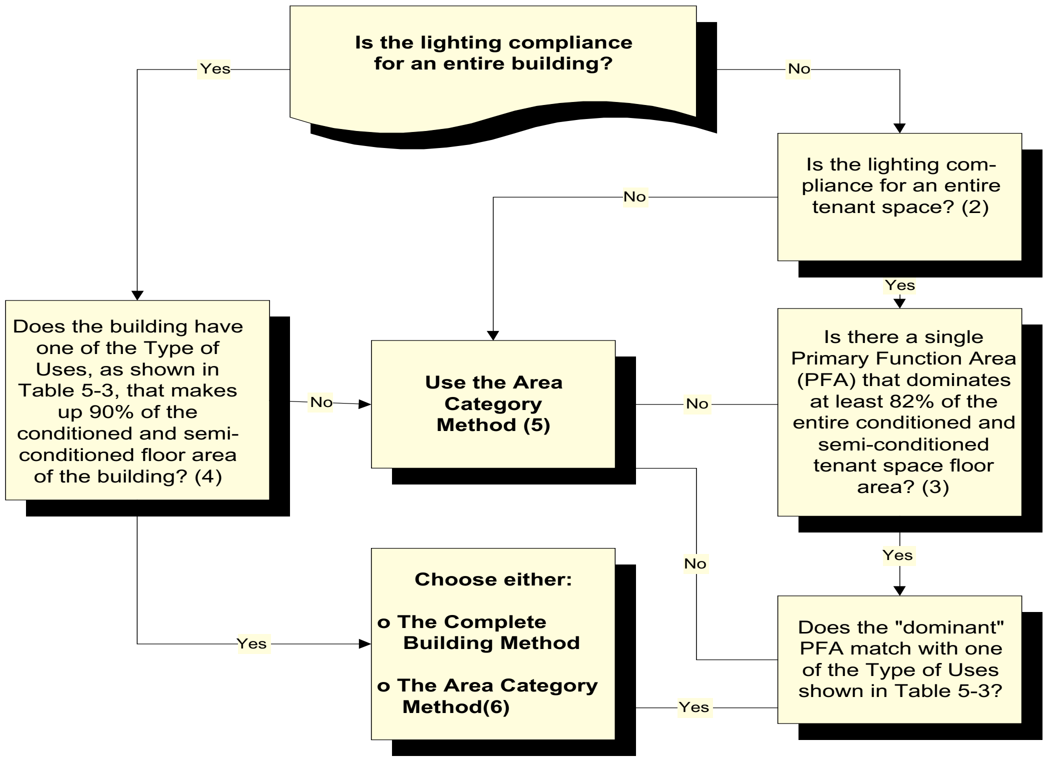
As an option, an entire tenant space can use the Complete Building Method when at least 82 percent of the permitted space is one of the primary functions listed in Table (see Figure 5-22 and Examples 5-15 through 5-17).

A tenant space is part of a building leased or used by a single tenant that is separated from other tenants by demising partition(s).

E. Summary

Under the prescriptive approach for lighting, one of the three methods discussed above, the Complete Building Method, the Area Category Method, or the Tailored Method, is used to determine the Allowed Lighting Power for the building. This value sets the upper limit for lighting power in the building. The next step is to calculate the Actual Lighting Power (with adjustments, if applicable). The Actual Lighting Power (adjusted) may not exceed the Allowed Lighting Power. See Section 5.2.4 for the procedures used to calculate Actual Lighting Power and its adjustments. When using Complete Building, Area Category, or Tailored Method, the lighting allotment must be based on area intended only for occupancy, or complete lighting plans must be submitted.

Figure 5-22– Lighting Power Density Calculation Flowchart. Complete Building Method and Area Category Method (1)



(1) Lighting compliance can also be achieved using the Tailored Method or the Performance Method. The lighting power portion of the Performance allowed budgets is determined by selecting the appropriate Complete Building or Area Category uses or function types, in accordance with the modeling rules shown in the flowchart above. The Tailored method may also be used to establish the lighting portion of the Performance Method allowed budget.

(2) A tenant space is a part of the building leased or used by a single entity that is separated by demising partitions from other tenants. The Complete Building Method may not be used for permits issued for partial tenant spaces. Multiple tenant spaces, when making up less than an entire building but permitted together, may each use the Complete Building Method by showing that EACH space meets the requirements of the Complete Building Method.

(3) PFA = Primary Function Area. All Primary Function Areas are listed in Table 5-4 of this Manual. The "dominant" PFA refers to the Function Area with the largest floor area among all Function Areas contained within a tenant space.

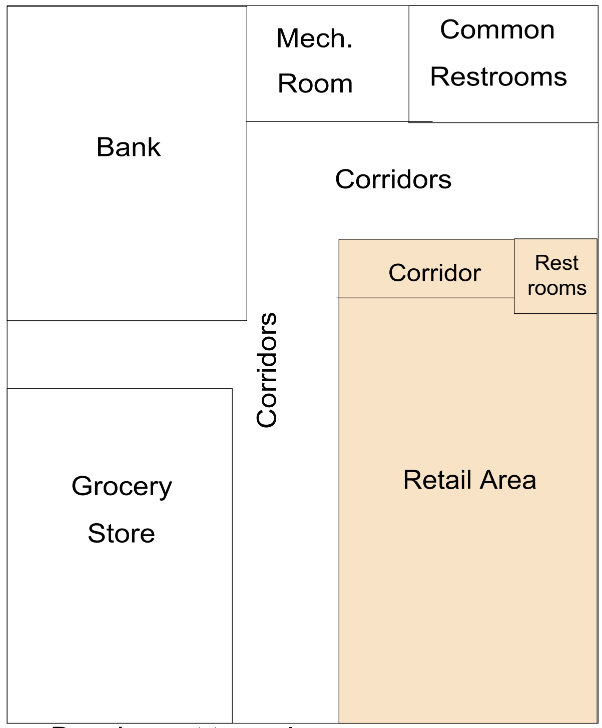
(4) Type of Use (TOU) is defined as a single type of use, as used in this Manual and listed in Table 5-3. To determine the AREA of the TOU, the following areas shall be included, provided they serve the primary use function: Lobbies, Corridors, and Restrooms.

(5) When using the Area Category Method, breakout separate Function areas into separate area categories, such as Retail Function, Corridor, Restroom, and Commercial Storage Functions.

Example 5-19– Simplified Lighting Flowchart, New Building

Question

If the figure below is a new building, what is the allowed lighting power for the entire building?



Drawing not to scale

Function	Area	%of Area
Non-Retail:		
Bank	4,000	28%
Grocery Store	3,500	24%
Mechanical Room	200	1%
Common Restrooms	300	2%
Common Corridors	1,000	7%
Total Non-Retail	9,000	62%
Retail:		
Retail Area	4,700	32%
Retail Restrooms	200	1%
Retail Corridors	600	4%
Total Retail	5,500	38%
Total Building	14,500	100%

Procedure

Using the flowchart in Figure 5-22– Lighting Power Density Calculation Flowchart. Complete Building Method and Area Category Method (1):

1. Is the lighting compliance for an entire building? *Yes*

2. Does the building have one of the Type of Uses that makes up 90 percent of the conditioned and semi-conditioned floor area of the building? *No* (the largest Type of Use category is Retail which occupies 38 percent of the conditioned floor area of the entire building).

Calculate the allowed lighting power by the Area Category Method.

Area Category Method:

Function	Area	W/ft^2	Watts
Bank	4,000	1.4	5,600
Grocery Store	3,500	1.6	5,600
Mechanical Room	200	0.7	140
Common Restrooms	300	0.6	180
Common Corridors	1,000	0.6	600
Retail Function	4,700	2.0	9,400
Retail Restrooms	200	0.6	120
Retail Corridor	600	0.6	360
Total Building Lighting Power		22,000	

Answer

The allowed lighting power is 22,000 watts.

Example 5-20– Simplified Lighting Flowchart, Alteration

Question

If the figure in Example 5-19 is an existing building and the retail store is being renovated, what is the allowed lighting power for the retail store?

Procedure

Using the flowchart in Figure 5-22:

1. Is the lighting compliance for an entire building? *No*

2. Is the lighting compliance for an entire tenant space? *Yes*

3. Is there a single PFA that dominates at least 82 percent of the entire conditioned and semi-conditioned tenant space floor area? *Yes* (The permit is for one tenant (retail store), and the retail function area is greater than 82 percent of the entire retail store (4,700/5,500 = 0.855).)

4. Does the dominant PFA match with one of the primary Types of Uses shown in Table 5-3? *Yes*

Calculate the allowed lighting power by either the Complete Building Method, or the Area Category Method.

Complete Building Method:

Allowed lighting power is 5,500 x 1.7 - 9,350 Watts

Area Category Method:

Function	Area	W/ft²	Watts
A) Retail	4,700	2.0	9,400
B) Restrooms	200	0.6	120
C) Retail Corridor	600	0.6	360
Total Allowed Lighting Power			9,880

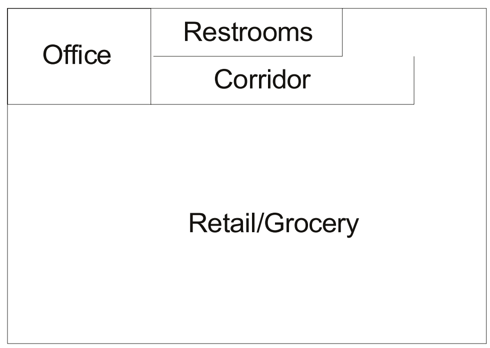
Answer

The allowed lighting power is 9,350 Watts using the Complete Building Method and 9,880 Watts using the Area Category Method.

Example 5-21– Simplified Lighting Flowchart, Retail/Grocery Combination

Question

What is the allowed lighting power for the Retail Grocery store combination in the figure below?



Drawing not to scale

Function	Area	% Total of Area
Retail	5,750	63%
Grocery	2,150	23%
Retail Office	450	5%
Restrooms	300	3%
Corridors	550	6%
Total	9,200	100%
Retail Type of Use	6,600	72%

Answer

Procedure

Using the flowchart in Figure 5-22:

1. Is the lighting compliance for an entire building? *Yes*

2. Does the building have one of the Type of Uses that makes up 90 percent of the conditioned and semi-conditioned floor area of the building? *No* (There are several Primary Function Areas including retail, grocery, office, restroom and storage. However, the retail, which includes retail, restrooms and corridor functions, makes up only 72 percent of the conditioned floor area. Note that the office function is a separate Type of Use and therefore excluded from the retail Type of Use calculations.)

Calculate the allowed lighting power by the Area Category Method.

Function	Area	W/ft^2	Watts
Retail	5,750	2.0	11,500
Grocery	2,150	1.6	3,440
Office	450	1.3	585
Restrooms	300	0.6	180
Corridor	550	0.6	330
Total Allowed Lighting Power			16,035

The allowed lighting power is 16,035 Watts.

5.2.3 Performance Approach

The performance approach provides an alternative method to the prescriptive approach for establishing the Allowed Lighting Power for the building.

Under the performance approach, the energy use of the building is modeled using a computer program approved by the *Energy Commission* using rules published in the Alternative Calculation Method (ACM) Manual. In this energy analysis, the standard lighting power density for the building is determined by the computer program based on occupancy type, in accordance with the Complete Building, Area Category, and Tailored rules described above (see Section 6.1 for details). This standard lighting power density is used to determine the energy budget for the building.

When a lighting permit is sought under the performance approach, the applicant uses a proposed lighting power density to determine whether or not the building meets the energy budget. If it does, this proposed lighting power density is automatically translated into the Allowed Lighting Power for the building (by multiplying by the area of the building).

If the building envelope or mechanical systems are included in the performance analysis (because they are part of the current permit application), then the performance approach allows energy trade-offs between systems that can let the Allowed Lighting Power go higher than any other method. Alternatively, it allows lighting power to be traded away to other systems, which would result in a lower Allowed Lighting Power. This flexibility in establishing Allowed Lighting Power is one of the more attractive benefits of the performance approach.

When tailored lighting is used to justify increases in the lighting load, a lower lighting load cannot be modeled for credit. The standard design building uses the lesser of allowed watts per square foot, or actual lighting power, to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on the lighting plans. This value must be equal to, or greater than, the allowed watts per square foot.

When the Performance Approach is used, the LTG-2: Performance Approach form, or a similar form produced by an approved computer method, must be included in the compliance submittal. Refer to Section 6.1 for a more complete description of the treatment of lighting systems under the performance approach.

5.2.4 Actual Lighting Power (Adjusted)

Once the Allowed Lighting Power is determined by one of the prescriptive or performance approach, it can be compared to the Actual Lighting Power (adjusted) in the building design.

The designed or Actual Lighting Power is simply the sum of the wattages of all planned permanent and portable lighting fixtures in the building, based on the same conditioned floor area as was used to calculate the Allowed Lighting Power.

The Actual Lighting Power may be adjusted through lighting control credits if optional automatic lighting controls are installed.

The Actual Lighting Power does not necessarily include every light in the building. There are a number of lighting applications that are exempted from the *Standards* limits on lighting power.

A. Exempt Lighting (§146(a)5)

The lighting applications which are exempted from the Actual Lighting Power calculation are listed below:

A. Lighting for theme parks and special effects lighting for dance floors (note that this does not include 'regular' spaces that do not require special lighting- for example, administrative offices and retail areas within the theme park are *not* exempt);

B. Lighting for film studios;

C. Lighting for exhibits or for theatrical and other live performances, in exhibit, convention areas, and in hotel function areas, if the lighting is an addition to a general lighting system, and if the lighting is controlled by a multi-scene or theatrical cross-fade control station accessible only to authorized operators;

D. Specialized local lighting installed in non-lighting equipment by its manufacturer (this includes all decorative neon lighting and all signs with interior lighting);

E. In medical and clinical buildings, examination and surgical lights, low-level night lights, and lighting integral to medical equipment;

F. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment;

G. Interior lighting in refrigerated cases;

H. Lighting for plant growth or maintenance, if it is equipped with an automatic 24-hour time switch that has program backup capabilities that prevent the loss of the switch's program and time setting for at least 10 hours if power is interrupted;

I. Lighting equipment that is for sale;

J. Lighting demonstration equipment in lighting education facilities;

K. Lighting that is required for exit signs subject to Section 1003.2.8 of the UBC, if it has an input power rating of five watts per illuminated face or less;

L. Exit way or egress illumination that is normally off and that is subject to Section 1003.2.9 of the UBC;

M. Exit way or egress lighting whose switching is regulated by Article 700 of the State Electrical Code (Title 24, Part 3);

N. In hotel/motel buildings, lighting in guest rooms;

O. In high-rise residential buildings, lighting in living quarters;

P. The lighting system using the least wattage in a redundant lighting system interlocked or otherwise controlled to prohibit simultaneous operation of more than one lighting system.

Q. Hard-wired neon lighting in signs is exempt.

B. Actual Lighting Power Calculation (§146(a))

For calculating the actual lighting power, wattages of all planned permanent, and portable (including planned portable), including hard wired and plug-in lighting systems shown on the plans at the time of permitting, must be considered (except those exempt under §146(a)5). This includes track lighting systems, chandeliers, portable free standing lights, lights attached to workstation panels, movable displays and cabinets, and internally illuminated case work for task or display purposes. Sufficient supporting evidence (from manufacturer's catalogs or values from independent testing lab reports) must be submitted to and accepted by the building authority. The individual signing the lighting plans must clearly indicate on the plans the actual power for the portable lighting systems in the area (§146(a)2).

The calculation of Actual Lighting Power is accomplished with the following steps:

1. Determine the watts for each type of fixture. This includes both the lamp and the ballast wattage. These are interdependent, so the wattage of a particular lamp/ballast combination is best determined from reputable manufacturer's test data. Default values from Table B-11 in Appendix B may be used for standard lamp and ballast combinations (see Determining Luminaire Wattage for details).

2. Determine the number of each fixture type in the design.

3. Multiply the fixture wattages by the numbers of fixtures and sum to obtain the building total Actual Lighting Power in watts (this includes wattages of portable lighting systems for office spaces).

4. Adjust for lighting control credits, if applicable (see Section 5.2.5).

Portable Lighting Systems (§146(a)1)

Portable lighting fixtures are often added to office spaces after the building is occupied. If the actual wattage of portable lighting is not known at the time of permitting then the *Standard* requires that a additional lighting power of 0.2 W/ft^2 be included in determining the actual lighting power density (§146(a)1). Office spaces with areas equal to or less than 250 ft^2 enclosed by floor-to-ceiling permanent partitions, are exempt from this requirement. Note that the portable lighting requirement applies to all office spaces with planned portable lighting systems regardless of the primary function area of the building and does *not* apply to enclosed (floor-to-ceiling permanent partition) office spaces with floor areas less than 250 ft^2. This requirement will apply to most buildings with typical open office type of layouts. However, once portable lighting systems have been installed in the space, the building official may require that the actual lighting power of the space be recalculated and resubmitted taking into account the actual wattage of the installed portable systems.

For all spaces, the actual wattage of all planned permanent and planned portable lighting shown on the plans at the time of permitting shall be included in determining the actual lighting power density. This is provided sufficient supporting evidence (from manufacturer's catalogs or values from independent testing lab reports) is submitted to and accepted by the building authority. The individual signing the lighting plans must clearly indicate on the plans the actual power for the portable lighting systems in the area (§146(a)2).

If no portable lighting systems have been planned for an office space or if the lighting system documentation shows less than 0.2 Watts/ft^2 of portable lighting, the designer must conclusively establish that the permanent lighting fixtures in the space meet its lighting needs, without having to augment with portable lighting in the future. This must be achieved by a methodical and complete point-by-point analysis using a lighting simulation tool. Average illuminance calculations are not acceptable for determining that a lighting system meets lighting requirements of the space. All assumptions that were critical to arriving at the simulation model must be submitted as an attachment to Form LTG-1 Part 3 of 3. This documentation must include information on luminaire layout (accompanied by furniture layout including modular furniture walls, shelves and cabinets), location, brand, model, and performance characteristics of all luminaires in the space. In addition, the documentation must include the luminaires, luminaire spacing, surface reflectance, ballast factors, lamp lumens, various loss factors, and all lighting design calculations. The resultant minimum-to-maximum or minimum-to-average ratios (typically generated by lighting simulation tools) must also be included in the submittal. The designer is responsible for providing all of the information that the building inspector may need to clearly understand that less than 0.2 watts/ ft^2 of portable lighting will be needed, including describing the Design Intent (based on IESNA recommended design criteria) and including target illumination ratios for comparison to the proposed lighting design. See Table 1B and Table 1C on Form LTG-1 Part 3 of 3 Section 5.3.1C).

*Example **5**-22– Portable Lighting, Area less than 250 ft^2*

Question

A retail building has two enclosed office spaces (120 ft^2 each) with floor-to-ceiling permanent partitions, for store managers. Should calculations for installed lighting power include an additional 0.2 W/ft^2 to account for portable lighting for these spaces?

Answer

No. The enclosed spaces are exempt from the additional 0.2 W/ft^2 requirements because their area does not exceed 250 ft^2.

*Example **5**-23– Portable Lighting, Complete Building Approach*

Question

A 8,000 ft^2 office building is to be built. At the time of permit application, the actual wattage of planned portable lighting for the office area is not known and no portable lighting is shown on the plans. Further, the percentage of office areas versus support areas is not known at the time of permitting. Using the Complete Building Method, how does this affect the Installed Lighting Power calculation for the building?

Answer

The *Standard* requires that a portable lighting power of 0.2 watts per square foot be included in the calculation of Installed Lighting Power for office buildings with areas greater than 250 ft^2. However, since the percentage of office areas versus support areas is not known in the building, the 0.2 watts per square foot should be added to the Installed Lighting Power of the permanent fixtures installed in the entire 8000 ft^2 of office space.

*Example **5**-24– Portable Lighting, Complete Building Approach*

Question

A 8,000 ft^2 office building is to be built. The building contains 2000 ft^2 of corridors, restrooms, and storage rooms. At the time of permit application, the actual wattage of planned portable lighting for the office area is not known and no portable lighting is shown on the plans. Using the Complete Building Method, how does this affect the Installed Lighting Power calculation for the building?

Answer

The *Standard* requires that a portable lighting power of 0.2 watts per square foot be included in the calculation of Installed Lighting Power for office buildings with areas greater than 250 ft^2. 0.2 watts per square foot should be added to the Installed Lighting Power of the permanent fixtures installed in the 6000 ft^2 of office space. All other spaces (2000 ft^2 of corridors, restrooms, and storage rooms) are exempt from this requirement.

*Example **5**-25– Portable Lighting, Area less than 250 ft^2*

Question

A small 200 ft^2 Office Building is to be built. At the time of permit application, the actual wattage of the planned portable lighting is not known and no portable lighting is shown on the plans. How does this alter the Installed Lighting Power calculation?

Answer

The Installed Lighting Power calculation remains unaltered. No portable lighting power is required to be included in the calculation of Installed Lighting Power for office buildings with areas equal to or less than 250 ft^2.

*Example **5**-26– Portable Lighting, non-Office Primary Function Areas*

Question

A 5000 ft^2 Retail Building, which includes a 300 ft^2 administrative office space and other spaces (as listed below), is to be built. At the time of permit application, the actual wattage of planned portable lighting is not known and no portable lighting is shown on the plans. How will the Installed Lighting Power for the building be calculated?

Function	Area
Office	300
Common Restrooms	200
Common Corridors	500
Retail Function	3,000
Total Building Area	4,000

Answer

Although office is *not* the primary function of the building, an additional 0.2 watts per square foot must be added to the Installed Lighting Power because the area of the space is greater than 250ft^2. The remaining area is exempt from this requirement.

Determining Luminaire Wattage (§130(d))

For most fixture types, determining the luminaire wattage is straightforward. There are, however, a few types that require special consideration. The Standard determines the luminaire wattage to be counted towards calculating installed interior lighting power based on lamps, ballasts, and luminaire type.

Incandescent and Tungsten-Halogen Luminaires Medium Screw Base Sockets without Permanently Installed Ballasts (§130(d)1)

The wattage of incandescent or tungsten-halogen luminaires with medium screw base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaire. Medium screw base sockets are typically found in fixtures that require a screw-in type lamp. They are the most common lamp bases for incandescent lamps (the ordinary type of light bulb that generates light from a glowing filament). These bases are used for a wide range of lamp wattages. These fixtures present a special situation when calculating Actual Lighting Power, because the wattage of the lamps can be easily changed at any time. The plans should specify the maximum allowed lighting power for each luminaire so that installers understand not to install luminaires with higher ratings.

Luminaires with Permanently or Remotely Installed Ballasts (§130(d)2)

The wattage of luminaires with permanently installed or remotely installed ballasts shall be the operating input wattage of the specified lamp/ballast combination based on values from manufacturer's catalogs or values from independent testing lab reports.

Track Lighting (§130(d)3&4)

Track lighting presents a special situation when calculating Actual Lighting Power, because the number and type of luminaires can be easily changed at any time. The wattage for track lights on standard voltage tracks shall be the volt-ampere rating of the current limiter controlling the luminaires (provided the current limiter is an integral part of the track and can only be replaced by manufacturer authorized technicians and the VA rating of the current limiter is clearly marked on the track and is readily available for the building officials' field inspection without opening the fixture or panels), *or* the higher of:

(a) total luminaires wattage proposed to operate on each track, or

(b) 45 watts per linear foot

Low voltage tracks, cable conductors, rail conductors, and other low voltage flexible lighting systems which are serviced through permanently installed transformers must use the specified wattage of the transformer as the Actual Lighting Power of the track.

In some situations, extra length of track is desired to provide greater flexibility in locating lighting fixtures. In these cases, the designer can limit the Actual Lighting Power by providing interlock switching that limits the circuits (and therefore the electric capacity) of track lighting that can be operated simultaneously.

Track lighting for use in exhibit areas (museums, exhibit center lighting for exhibits, etc.) that meet the requirements of the exempt lighting listed in Section 5.2.4A (Item C. in list) is considered exempt lighting.

Example 5-27– Track Lighting Power

Question

What is the wattage of a six foot length of track lighting that has three 150 watt listed fixtures with 60 watt, medium base lamps proposed?

Answer

- Based on medium base socket fixtures the total wattage is 450 watts (three fixtures at 150 listed watts each).
- Based on the length of track the wattage is 270 watts (6 ft x 45 w/ft).

The Actual Lighting Power of the track is the larger of the two, or 450 watts.

Other Lighting (§130(d)5)

The wattage for all other lighting equipment shall be the specified wattage of that lighting system.

C. Theme Parks

Specialty lighting within theme parks are exempt from the lighting power density calculations. However, all other lighting must comply with the Nonresidential Energy Efficiency Standards. The *Standards* must be enforced for primary function areas in conditioned areas that are included in Table 5-3 of this Manual. The primary function areas in theme parks must be quantified in Title 24 lighting documentation, and are not exempt from the lighting power density requirements. These include, retail, restrooms, restaurants, lobbies, ballrooms, theaters and other primary function areas in theme parks. The treatment of these primary function areas is no different for theme parks than for other building projects. However, the lighting that is used strictly for entertainment in theme parks, such as the entertainment production lighting related only to presenting the theme of the theme park, may be exempted from Title 24 lighting power density compliance. An example of a theme park may be a large amusement park, which includes carnival rides, shows, and exhibits.

D. Exit Way and Egress Lighting

Lighting that is required for exit signs subject to Section 1003.2.8 of the UBC and has an input power rating of five watts per illuminated face or less, and exit way or egress illumination that is normally off and that is subject to Section1003.2.9 of the UBC, is exempt from lighting power calculations.

Also, exit way or egress lighting whose switching is regulated by Article 700 of the State Electrical Code (Title 24, Part 3) (Article 700), is also exempt from lighting power calculations. Article 700 specifies that (Article 700 must be consulted for the for complete list of requirements of emergency systems):

Emergency systems are those systems legally required and classed as emergency by municipal, state, federal, other codes, or by any governmental agency having jurisdiction,

These systems are intended to automatically provide illumination to designated areas in the event of failure of normal power supply,

These systems must be separately switched from the general lighting systems,

These systems shall be so arranged that only authorized persons have control of the emergency lighting,

These systems have an emergency power supply independent of the general lighting power supply, or are equipped with two or more separate and complete systems with independent power supply, each system providing sufficient current for emergency lighting purposes.

The amount illumination provided by the emergency lighting exempted from the lighting power calculations may not exceed the recommended illumination levels required by applicable codes.

Note that Section 5.2.1B, the Area Controls of the Mandatory Measures, specifies that lighting in areas within a building that must be continuously illuminated for reasons of building security or emergency egress are exempt from the switching requirements of the Area Controls of the Mandatory Measures for a maximum of 0.5 watt per square foot. These lights must be installed in areas designated as security or emergency egress areas on the plans, and must be controlled by switches accessible only to authorized personnel. The remaining lighting in the area, however, is still subject to the area switching requirements.

5.2.5 Automatic Lighting Control Credits (§146(a)4)

The watts of connected lighting within the building may be adjusted to take credit for the benefits of certain types of automatic lighting controls. A list of the controls that qualify for these credits is shown in Table 5-10.

The lighting control credits reduce the Actual Lighting Power, giving a lower adjusted lighting power. This makes it easier to meet the Allowed Lighting Power requirement.

Automatic lighting controls can reduce the amount of energy used for lighting; a credit is permitted when the control types indicated in Table 5-10 are used. See also Section 5.1.1C.

In order to qualify for the power savings adjustment, the control system or device must be certified (see Section 5.2.1A), and must control all of the fixtures for which credit is claimed. At least 50 percent of the light output of the controlled luminaire must fall within the applicable type of space listed in Table 5-10. Additionally, credits may not be combined, with the exception of those listed as Combined Controls in Table 5-10on the following page. Daylighting control credits are only available for luminaires within daylit zones, as defined in Section 5.2.1D of this manual.

5.2.6 Alterations

When altering lighting component(s) in an existing conditioned building, compliance requirements vary with the details and extent of the alterations. Some or all mandatory measures may apply, and compliance with current lighting requirements (watts/ft^2) may also apply. The mandatory requirements include certification of any new lamps and ballasts that are installed if they are the type regulated by the Appliance Efficiency Regulations. Any new lighting controls must meet minimum performance requirements. In addition, control and circuiting requirements (§131 and §132) apply as follows:

- Independent switching within a space or room is required if ceiling height partitions are installed or moved, creating a new enclosed space.
- Bi-level illumination requirements apply if the alteration consists of rewiring and any individual enclosed space within the altered area exceeds 100 square feet and has more than 0.8 watts per square foot.
- Separate switching for daylit areas is required if the alteration involves rewiring and any individual enclosed space within the altered area exceeds 250 square feet (see **Daylit Areas**, Section 5.2.1D).
- Shut-off control requirements apply if the area in which the lighting alteration is occurring exceeds 5,000 square feet. The altered area is the area lit by the particular fixture(s) being altered. For general distribution lighting, determine the area lit using the skylight/daylit area approach (see Example 5-6). For task lighting, the area lit is expected to be narrower.
- Tandem wiring is required if the alteration involves rewiring.

If an alteration involves replacing more than 50 percent of the lighting fixtures or results in an increase in the connected lighting load, compliance with current standards for wattage levels is also required (see Example 3-10). When it is necessary to calculate the existing wattage to demonstrate that the alteration does not result in an increased lighting level, use the same methodology used for new lighting installations found in this section. Document both "existing" and "new" lighting power on form LTG-2.

Only those areas of the building enclosed by floor-to-ceiling partitions in which lighting fixtures are being replaced or the connected lighting load is being increased, need to meet lighting requirements of the *Standard*s. Areas of the building enclosed by floor-to-ceiling partitions in which no lighting is being altered do not need to meet lighting requirements of the *Standard*s. The basis for determining if more than 50 percent of fixtures are being replaced is the permitted space (not the building space), excluding any enclosed areas that are not receiving new light fixtures. Enclosed areas are areas that are surrounded by permanent floor-to-ceiling partitions. For alterations, the permitted space is usually not an entire building, and may not be an entire tenant space. Building departments will often define "permitted space" to include only those areas where alterations are proposed.

Note: See 5.2.2D (Simplification for Tenant Spaces) for circumstances under which the complete building method may be used for alterations.

Semi-Conditioned Building: In an existing semi-conditioned space, the lighting alteration requirements for conditioned buildings shall apply. When a space is unconditioned and is converted to semi-conditioned no requirements apply. If an unconditioned or semi-conditioned building is conditioned then lighting, envelope and mechanical requirements for additions shall apply (see Section 2.2).

Semi-Conditioned Space is an enclosed nonresidential space that is provided with wood heating, cooling by direct or indirect evaporation of water, mechanical heating that has a capacity of 10 Btu/(hr ft^2) or less, mechanical cooling that has a capacity of 5 Btu/(hr ft^2)or less, or is maintained for a process environment as set forth in the *Standards* definition of DIRECTLY CONDITIONED SPACE (§101).

Example 5-28– Lighting Alterations, Allowed Lighting Power

Question

All light fixtures are being replaced in one enclosed room of a commercial tenant space. The entire tenant space currently has a total of 25 light fixtures. The altered room will receive a total of eight new light fixtures. How much lighting power is allowed for the new lighting?

Answer

Since all lighting fixtures within the enclosed area (room) are being replaced, then more than 50% of the lighting in the applicable space (the enclosed room) is new. Therefore, the lighting power in this space must meet the requirements for new construction.

Example 5-29– Lighting Alterations, Permitted Space

Question

All light fixtures in one enclosed room of a commercial tenant space are being replaced. The permitted space however, covers the entire tenant space due to a proposed replacement HVAC system. How much lighting power is allowed for the new lighting?

Answer

Though the entire tenant space is the permitted space, only the room where new lighting is proposed is evaluated for determining whether more than 50% of the light fixtures are new. In this case, 100% of the lighting in this room is being altered, so the lighting power in this room must meet the requirements for new construction.

Example 5-30– Lighting Alterations, Allowed Lighting Power

Question

All light fixtures in a men's clothing department are being replaced. The men’s clothing department covers one-third of main open sales floor of the department store. The permit space covers only the men’s clothing department floor area. How much lighting power is allowed for the new lighting?

Answer

Although the men’s clothing department covers only one-third of the entire enclosed floor area, it still constitutes 100% of the permitted space. Only this area should be considered for the basis of determining if more than 50 percent of fixtures are being replaced. In this case, 100% of the lighting in area is being altered, so the lighting power in this area must meet the requirements for new construction.

Table 5-10 - Power Savings Adjustments for

TYPE OF CONTROL	TYPE OF SPACE	FACTOR
Occupant sensor With separate sensor for each space	Any space <250 square feet enclosed by opaque floor-to-ceiling partitions; any size classroom, corridor, conference or waiting room	0.20
	Rooms of any size that are used exclusively for storage	0.60
	Greater than <250 square feet	0.10
Dimming system		
Manual	Hotels/motels, restaurants, auditoriums, theaters	0.10
Multiscene programmable	Hotels/motels, restaurants, auditoriums, theaters	0.20
Tuning	Any space	0.10
Automatic time switch control device	<250 square feet and with a timed manual override at each switch location required by §131 (a), and controlling only the lights in the area enclosed by ceiling-height partitions.	0.05
Combined controls		
Occupant sensor with programmable multiscene dimming system	Hotels/motels, restaurants, auditoriums, theaters	0.35
Occupant sensor with a separate sensor for each space used in conjunction with daylighting controls and separate sensor for each space	Any space <250 square feet within a daylit area and enclosed by opaque floor-to-ceiling partitions	0.10 (may be added to daylighting control credit)

Automatic Daylighting Controls (Stepped/Dimming)			
	WINDOWS Window Wall Ratio		
Glazing Type	20%	20% to 40%	40%
VLT> 60%	0.20 0.30	0.30 / .040	0.40/0.40
VLT> 35 and < 60%	0/0	0.20/0.30	0.30/0.40
VLT< 35%	0/0	0/0	0.20/0.40
	SKYLIGHTS Percentage of Gross Exterior Roof Area		
Glazing Type	< 1%	1% to 3%	>3%
VLT > 60%	0/0.30	0.15/0.40	0.30/0.40
VLT>35 and < 60%	0/0.20	0/0.30	0.15/0.40
VLT < 35%	0/0.10	0/0.20	0/0.30

5.3 Lighting Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the recommended forms and procedures for documenting compliance with the lighting requirements of the *Standards*. It does not describe the details of the requirements; these are presented in Section 5.2, Lighting Design Procedures. The following discussion is addressed to the designer preparing construction documents and compliance, and to the building department plan checkers who are examining those documents for compliance with the *Standards*.

The use of each form is briefly described below, and complete instructions for each form are presented in the following subsections. These forms may be included in the lighting equipment schedules on the plans, provided the information is in a similar format as the suggested form.

LTG-1: Certificate of Compliance: This form is required for every job, and it is required to appear on the plans.

LTG-2: Lighting Compliance Summary: This form is required for all submittals.

LTG-3: Lighting Controls Credit Worksheet: This form should only be required when calculating control credit watts.

LTG-4: Tailored LPD Summary and Worksheet: This form should only be required when calculating the Allowed Lighting Power using the Tailored Method. Part 1 should be submitted whenever this method is used, part 2 is used for Illuminance Categories E through I, and part 3 is used for display lighting.

5.3.1 LTG-1: Certificate of Compliance

The LTG-1 Certificate of Compliance form is in three parts. All parts must appear on the plans (usually near the front of the electrical drawings). A copy of these forms should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. With building department approval, the applicant may use alternative formats of these forms (rather than the official *Energy Commission* forms), provided the information is the same and in a similar format.

A. LTG-1 Part 1 of 3

Project Description

1. **PROJECT NAME** is the title of the project, as shown on the plans and known to the building department.
2. **DATE** is the date of preparation of the compliance submittal package. It should be on or after the date of the plans, and on or before the date of the building permit application.
3. **PROJECT ADDRESS** is the address of the project as shown on the plans and as known to the building department.
4. **PRINCIPAL DESIGNER - LIGHTING** is the person responsible for the preparation of the lighting plans, one of two people who sign the STATEMENT OF COMPLIANCE (see below). The person's telephone number is given to facilitate response to any questions that arise.
5. **DOCUMENTATION AUTHOR** is the person who prepared the energy compliance documentation. This may or may not be the principal designer (it may be a person specializing in energy standards compliance work). This person is not subject to the Business and Profession's Code. The person's telephone number is given to facilitate response to any questions that arise.

6. **ENFORCEMENT AGENCY USE** is reserved for building department record keeping purposes.

General Information

1. **DATE OF PLANS** is the last revision date of the plans. If the plans are revised after this date, it may be necessary to resubmit the compliance documentation to reflect the altered design. The building department will determine whether or not the revisions require this.
2. BUILDING CONDITIONED FLOOR AREA has specific meaning under the *Standards*. Refer to Section 2.2.1A for a discussion of this definition.

   The number entered here should match the floor area entered on form ENV-1
3. **CLIMATE ZONE** of the building. Refer to Appendix C.
4. **BUILDING TYPE** is specified because there are special requirements for high-rise residential and hotel/motel guest room occupancies. All other occupancies that fall under the Nonresidential Standards are designated "Nonresidential" here. It is possible for a building to include more than one building type. See Section 2.2 for the formal definitions of these occupancies.
5. **PHASE OF CONSTRUCTION** indicates the status of the building project described in the documents. Refer to Section 2.2 for detailed discussion of the various choices.

   a. NEW CONSTRUCTION should be checked for all new buildings (see Section 2.2.2F), newly conditioned space (see Section 2.2.2B) or for new construction in existing buildings (tenant improvements, see Section 2.2.2C), which are submitted for envelope compliance.

   b. ADDITION should be checked for an addition which is not treated as a stand-alone building, but which uses Option 2 described in Section 2.2.2E Additions.

   c. ALTERATION should be checked for alterations to existing building lighting systems. See Section 2.2.4.
6. **METHOD OF LIGHTING COMPLIANCE** indicates which method is being used and documented with this submittal:

   a. COMPLETE BUILDING should be checked if the lighting system complies using the complete building method, as documented on the LTG-2 Form

   b. AREA CATEGORY should be checked if the area category method, as documented on the LTG-2 form

   c. TAILORED should be checked if the tailored method of lighting compliance, with supporting documentation (LTG-2 and LTG-4) is submitted.

   d. PERFORMANCE should be checked when the performance method is used to show compliance. All required performance documentation must be included in the plan check submittal when this method is used.

Statement of Compliance

The Statement of Compliance is signed by the person responsible for preparation of the plans for the building. This person is also responsible for the energy compliance documentation, even if the actual work is delegated to someone else (the Documentation Author described above). It is necessary that the compliance documentation be consistent with the plans. The Business and Professions Code governs who is qualified to prepare plans, and therefore to sign this statement; check the appropriate box that describes the signer's eligibility.

Applicable sections from the Business and Professions Code (based on the edition in effect as of August 2000), referenced on the Certificate of Compliance, are provided below:

5537. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

6737.1. (a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of woodframe construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of woodframe construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of woodframe construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of woodframe construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for woodframe construction found in the most recent edition of Title 24 of the California Administrative Code or tables of limitation for woodframe construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the direct supervision of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

6737.3. A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible supervision of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person.

Lighting Mandatory Measures

This portion requests the location of notes clarifying the inclusion of the mandatory requirements. Notes should be included on the plans to demonstrate compliance with mandatory requirements of the *Standards*.

Following are examples of the notes that should be rewritten to actual conditions. A note for each of the items listed should be included, even if the note states “not applicable”.

Example 5-31– Sample Notes: Lighting Mandatory Measures

Building Lighting Shut-off

The building lighting shut-off system consists of an automatic time switch, with a zone for each floor.

Override for Building Lighting Shut-off

The automatic building shut-off system is provided with a manual accessible override switch in sight of the lights. The area of override is not to exceed 5,000 square feet.

Automatic Control Devices Certified

All automatic control devices specified are certified, all alternate equipment shall be certified and installed as directed by the manufacturer.

Fluorescent Ballast and Luminaires Certified

All fluorescent fixtures subject to certification and specified for the projects are certified.

Tandem Wiring for Two-Lamp Ballast's

All one and three lamp fluorescent fixtures are tandem wired with two (2) lamp ballast where required by *Standards* §132; or

All three lamp fluorescent fixtures are specified with electronic high-frequency ballast's and are exempt from two-lamp tandem wiring requirements.

Individual Room/Area Controls

Each room and area in this building is equipped with a separate switch or occupancy sensor device for each area with floor-to-ceiling walls.

Uniform Reduction for Individual Rooms

All rooms and areas greater than 100 square feet and more than 0.8 watts per square foot of lighting load shall be controlled with Bi-level switching for uniform reduction of lighting within the room.

Daylit Area Control

All rooms with windows and skylights, that are greater than 250 square feet, and that allow for the effective use of daylight in the area shall have 50 percent of the lamps in each daylit area controlled by a separate switch; or

The effective use of daylight throughout cannot be accomplished because the windows are continuously shaded by a building on the adjacent lot. Diagram of shading during different times of year is included on plans.

Control of Exterior Lights

Exterior mounted fixtures served from the electrical panel inside the building are controlled with a directional photocell control and a corresponding relay in the electrical panel.

The above notes are only examples of wording. Each mandatory measure that requires a separate note should be listed on the plans.

To verify certification, use one of the following options:

1. The Energy Hotline can verify certification of appliances not found or;

2. The *Energy Commission*'s Web Site includes listings of energy efficient appliances for several appliance types. The web site address is www.energy.ca.gov/efficiency/appliances/

3. The complete appliance databases can be downloaded from the *Energy Commission*'s Internet at www.energy.ca.gov/efficiency/appliances/. This requires database software (spreadsheet programs cannot handle some of the larger files). To use the data, a user must download the database file (or files), download a brand file and a manufacturer file and then decompress these files. Then download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated.

Documenting the mandatory measures on the plans is accomplished through a confirmation statement, notes and actual equipment location as identified on the plans. The plans should clearly indicate the location and type of all mandatory control devices; such as manual switches, reduced level control, daylit area, controls, building shut-off and overrides, and exterior light controls.

B. LTG-1 Part 2 of 3

Part 2 of LTG-1 should be used to describe the lighting fixtures and control devices designed to be installed in the building. The information on this form may, with the approval of the building official, be incorporated into equipment schedules on the plans, rather than presented on the LTG-1 Part 2 form. If this is done, however, the same information should be included in one schedule in a format similar to the Energy Commission form.

Installed Lighting Schedule

a. **NAME** each luminaire type is described by name, code, type or symbol as shown on the plans.

b. **LUMINAIRE DESCRIPTION** lists the type of lighting fixture (Recessed Fluorescent Downlight, 2-Lamp, 4'strip, FT32T8, etc.).

Lamps

a. **TYPE DESCRIPTION** lists the type of lamp (Incandescent, Fluorescent or High-Intensity discharge, etc.).

b. **NO. OF LAMPS** lists the number of lamps per fixture. If track lighting is used, and the fixtures are not shown on the plans, the length of track is entered in this column.

c. **WATTS/LAMP** is the listed watts per lamp. For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column. For low voltage lighting, enter the voltage ampere (VA) rating of the transformer. For neon lighting it's required to be included in lighting wattage calculations, enter the transformer watts.

Ballast

a. **TYPE DESCRIPTION** indicates the ballast type: Standard energy saving magnetic (S), Electronic High Frequency (E), or Other (O). If E or O ballast types are used, the exact ballast type and model number should be specified on the plans.

b. **NO. OF BALLAST** lists the number of ballasts installed in each luminaire or fixture. Typically this value is 2.0, 1.0 or 0.5.

Luminaire

a. **NO. OF LUMINAIRE** lists the number of luminaire or fixtures.

b. **WATTS Per LUMINAIRE** indicates the total lamp and ballast wattage for each luminaire or fixture.

TOTAL WATTS enter total wattage of the luminaire or fixture, which includes both watts per lamp and ballast. Multiply the No. of Luminaire and Watts per Luminaire columns and enter total in the Total Watts Column.

EXTERIOR LIGHTING CONTROL AND EFFICACY REQUIREMENTS - Check either or both boxes that are applicable to exterior building lighting controls. See §130(c) and §131(f).

Mandatory Automatic Controls

The Mandatory Automatic Controls portion is where those devices meet the mandatory control requirements are listed, that would include devices for building shut-off, individual room control and control of exterior lights. **CONTROL LOCATION** lists the location(s) or room number(s) of the controls and should match the plans.

a. **CONTROL IDENTIFICATION** lists the symbol of the control and should match the plans.

b. **CONTROL TYPE** lists the type of certified control device used to meet the mandatory automatic control requirement.

c. **SPACE CONTROLLED** lists the location of controlled lights. Controls for Credit typical controls may be covered by general notation.

Controls for Credit

The Controls for Credit portion is similar to the Mandatory Automatic Controls portion. The only difference is in the last column, Luminaires Controlled.

a. **CONTROL LOCATION** lists the location(s) or room number(s) of the controls and should match the plans.

b. **CONTROL IDENTIFICATION** lists the symbol of the control and should match the plans. **CONTROL TYPE** lists the type of certified control device used to meet the automatic control requirement. Such controls are, occupant, daylight, dimming sensors etc.

LUMINAIRES CONTROLLED should list the luminaire type and quantity controlled for credit.

a. **TYPE** should use the same name as on the plans.

b. **# OF Luminaire** should indicate the number of luminaires of that type that are controlled by the control type. A general plan notation on the plans may cover all typical controls.

Notes to Field

This space is for use by the building department plans examiner to alert the field inspector to look for important inspection items.

C. LTG-1 Part 3 of 3

Part 3 of LTG-1 should be used to identify and account for all portable lighting fixtures in office areas in buildings (this form should be used to account for all portable lighting, both planned and unplanned). Note that this applies to all office spaces with planned portable lighting systems regardless of the primary function area of the building and does not apply to enclosed (floor-to-ceiling permanent partition) office spaces with floor areas less than 250 ft^2. Use Table 1A for unspecified portable lighting systems. Most buildings with typical open office type of layouts should use this approach. Use Table 1B if the specific portable lighting systems to be installed in the office space are known and documented on the plans. The documentation must include specific features of the portable lighting and identify the specific task areas that each portable lighting equipment will illuminate. Use Table 1C if no portable lighting fixtures are planned for the office space(s) and if detailed documentation of the lighting levels by overhead lighting are provided to show that they meet the lighting requirements of that space.

If lighting system documentation shows less than 0.2 Watts/ft^2 of portable lighting, the designer must demonstrate that the lighting design meets lighting needs without additional portable lighting. This must be demonstrated by a detailed point calculation method analysis using a lighting simulation tool. Average illuminance calculations are not acceptable for determining that a lighting system meets lighting requirements of the space. All assumptions used in the simulation model of the lighting design must be submitted as an attachment to form LTG-1 Part 3 of 3. This documentation must include information on luminaire layout (accompanied by furniture layout including modular furniture walls, shelves and cabinets), location, brand, model, and performance characteristics of all luminaires in the space. In addition, the documentation must include the coefficient of utilization (CU) for the luminaires, luminaire spacing, surface reflectance, ballast factors, lamp lumens, various loss factors, and all lighting design calculations. The resultant minimum-to-maximum or minimum-to-average ratios (typically generated by lighting simulation tools) must also be included in the submittal. The designer is responsible for providing all of the information that the building inspector may need to clearly understand that less than 0.2 watts/ ft^2 of portable lighting will be needed, including describing the Design Intent (based on IESNA recommended design criteria) and including target illumination ratios for comparison to the proposed lighting design.

Table 1A Portable lighting not shown on plans

a. **A. ROOM # OR ZONE ID** - enter the name of the room number or zone ID for space(s) that have more than 250 square feet of floor area. B. The DEFAULT lighting power density for this space is 0.2 watts/ft^2.

b. **B. DEFAULT** – 0.2 watts/ft^2 is the default lighting power density for portable lighting.

c. **C. AREA (ft^2)** – enter room or zone office area for the floor area of the space identified in column A.

d. **D. TOTAL WATTS** (B x C) – enter the total watts for each room or zone by multiplying the values in columns B and C.

COLUMN TOTALS – Sum the values in each of columns C and D and enter the result in the boxes at the bottom of Table 1A.

Table 1B Detailed lighting design - Portable lighting shown on plans

a. **A. ROOM # OR ZONE ID** – enter the name of the room number or zone ID for the space(s) that contains the task area(s) for which specific portable lighting system(s) and associated task areas have been shown on the plans. Use a separate line for each task area.

b. **B. PORTABLE LIGHTING DESCRIPTION(S) PER TASK AREA** – enter the type of lamp and fixture used for portable task lighting to illuminate each task area and include a detailed lighting design demonstrating how the lighting design meets the illumination needs throughout the space. Note that supporting documents include output forms from lighting software and drawings that clearly show the location, brand, model, and performance characteristics of all luminaires in the space. In addition, all properties of the space that effect lighting performance (like surface reflectance and furniture layout) must be clearly summarized on documentation attached to Form LTG-1 Part 3 of 3.The information needs to be traceable to specific types of portable lighting products that will be installed.

c. **C. LUMINAIRE(S) WATTS PER TASK AREA** – enter the total number of watts for all portable lighting used to illuminate each task area.

d. **D. TASK AREA (ft^2)** is the surface area in the space that will be served by the portable light. This may not be the same as the actual partition-to-partition area of the cubicle. It may be limited to the actual area served by the task lighting, or be limited to the desk area in the cubicle. There may be more than one task area in each ROOM # OR ZONE ID identified in column A. Each task area must be identified on the plans in a fashion that can be matched to the list of portable lighting.

e. **E. NUMBER OF TASK AREAS** – enter the number of task areas in column D for each room or zone identified in column A.

f. **F. TOTAL AREA (ft^2)** (D x E) – enter the results of column D multiplied times column E

g. **G. TOTAL WATTS** (C x E) – enter the results of column C multiplied times column E.

COLUMN TOTALS – sum up the values in each of columns F and G and enter the result in the boxes at the bottom of Table 1B.

Table 1C Detailed lighting design - Plans show portable lighting is not required

a. **A. ROOM # OR ZONE ID** – enter the name of the room number or zone ID for space(s) for which no portable lighting is required (as established by supporting documents and drawings). Note that supporting documents include output forms from lighting software and drawings that clearly show the location, brand, model, and performance characteristics of all luminaires in the space. In addition, all properties of the space that effect lighting performance (like surface reflectance and furniture layout) must be clearly summarized on documentation attached to Form LTG-1 Part 3 of 3.

b. **B. TOTAL AREA (ft^2)** – enter the areas of the spaces listed in A.

Building Summary – Portable Lighting

TOTAL AREA (ft^2) – enter the sum of the total areas from tables 1A, 1B, and 1C.

TOTAL WATTS enter the total watts of portable lighting from tables 1A and 1B. This number is entered on forms LTG-1 and LTG-2 under portable lighting.

D. LTG-2: Lighting Compliance Summary

Form LTG-2 (Lighting Compliance) should be completed and submitted with all applications, while LTG-3 (Control Credits) and LTG-4 (Tailored Method) should be included with LTG-2 only when that method is used. While these forms are not required to be on the plans (they may be submitted separately in the energy compliance package), the designer may include them in the lighting equipment schedules provided the information is in a similar format.

Actual Lighting Power

The Actual Lighting Power (Adjusted) is calculated by completing this form.

a. LUMINAIRE NAMES shall be listed by name or symbol.

b. DESCRIPTION should indicate a short list of the technical features.

c. NUMBER OF LUMINAIRES lists the quantity of each fixture type in the building. If track lighting is used, and the fixtures are not shown on the plans, the length of track is entered in this column.

d. WATTS PER LUMINAIRE lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track and incandescent medium base socket fixtures see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

e. CEC DEFAULT is a check to indicate if the wattage is a standard value from the data in Appendix B, Table B-11, or a nonstandard value. Nonstandard values must be substantiated with manufacturer's data sheets.

TOTAL WATTS is the product of the quantity of each luminaire listed times its watts per luminaire.

Subtotal the total watts for each luminaire and subtract the control credits, if any, from form LTG-3. The results are the Actual Lighting Power (Adjusted) for the building. This total cannot be greater than the Allowed Lighting Power calculated below.

Allowed Lighting Power

The Allowed Lighting Power is determined by calculating the maximum total watts of lighting that may be installed. There are four different methods that may be used. These methods may not be mixed in the same building permit application.

Complete Building Method

This method may only be used when plans and specifications for the entire building are included in the permit application.

a. BUILDING CATEGORY is taken from Table 5-3 for the occupancy of the building. If the building has a mixture of occupancies, the mixed occupancy rules determine the major occupancy of the building (the major occupancy must be at least 90 percent of the conditioned floor area). If there is not a major occupancy, this method may not be used.

b. WATTS PER SF for that building type is taken from Table 5-3 and entered here.

c. COMPLETE BUILDING AREA is the conditioned floor area of the entire building, including the conditioned floor area of minor occupancies.

d. ALLOWED WATTS is the product of the watts per square foot times the complete building area. This becomes the Allowed Lighting Power for the building.

Area Category Method

This method may be used when different primary function areas of a building are included in the permit application.

a. AREA CATEGORY is taken from Table 5-4 for the primary function of the area. If the building has a mixture of areas, each function area must be listed separately.

b. WATTS PER SF for that building type is taken from Table 5-4 and entered here.

c. AREA (SF) is the conditioned floor area of the primary function area measured from the inside of bounding partitions (Section 5.1.1A).

d. ALLOWED WATTS is the product of the watts per square foot times the primary function area. This becomes the Allowed Lighting Power for the area.

The sum of the Allowed Lighting Power for each primary function area is the Allowed Lighting Power for the building.

Tailored Method

When the Tailored Method is used, the LTG-4 forms, or a similar form, must be included in the compliance submittal.

TOTAL ALLOWED WATTS is entered here from line 4, of LTG-4: Tailored LPD Summary and Worksheet, Part 1 of 3.

E. LTG-3 Lighting Controls Credit Worksheet

When certain types of automatic lighting controls listed in Table 5-10 are used, a credit is permitted. This table also lists some restrictions that must be met in order to take credit for the controls.

Lighting control credits are documented on form LTG-3. This requires a specific listing of each device that is used for credit and listing those luminaires controlled by that device.

a. Room # Zone ID Column A list the room where the control device is controlling luminaires.

b. Lighting Control Description Column B lists a description of that device.

c. Plans Reference Column C indicates where on the plan set the controls are shown.

d. Room Area Column D indicates the area of the room in which the controls are located.

Daylighting

e. Room Ratio Column E is used to indicate the room ratio for determining the daylighting control credit and is described in Section 5.2.1D. The window wall ratio for the window in the room should be used for vertical daylighting configurations. The skylight well opening (at the ceiling level) to roof/ceiling area should be used for horizontal daylighting configurations.

f. Glazing VLT Column F is used to indicate the visible light transmittance of the aperture. The visible light transmittance is determined in Section 5.2.1D.

g. **Control Lighting in Watts Column G** is used to document the total watts of controlled lighting in each room.

h. **Lighting Adjustment Factor Column H** is used to indicate the Power Savings Adjustment Factor for that specific control device and is obtained from Table 5-10.

i. **Control Credit Watts Column I** is the sum of Column G (Control lighting in Watts) times Column H (Lighting Adjustment Factor).

The total Control Credit Watts (entered on LTG-3) is the sum of the Control Credit Watts in Column I. This credit is subtracted from the total installed watts to determine the Actual Lighting Power (Adjusted).

5.3.2 LTG-4: Tailored LPD Summary and Worksheet

The Tailored Method is the most detailed method of calculation for the Allowed Lighting Power. The Allowed Lighting Power is determined on the individual needs of each task. This method is appropriate for buildings that have unusual lighting needs and in some cases, can increase the Allowed Lighting Power to meet those needs. For a complete description of this method, refer to Section 5.2.2C of this Manual.

A. LTG-4: Part 1 of 3

This form should be submitted with all Tailored Method applications. It summarizes the results of the different parts of LTG-4, and includes the Allowed Lighting Power calculations for Illuminance Categories A, B, C and D.

Tailored Lighting Summary

The Allowed Watts is the summation for the building, included at the top of Part 1 of form LTG-4.

Line 1 is the buildings total allowed watts for Illuminance Categories A through D, and the Gross Sales Floor Area. This value is obtained from the bottom right corner of this form.

Line 2 is the buildings total allowed watts for illuminance categories E through I, and the Gross Sales Wall Area. This value is obtained from the Building Total entry on LTG-4, Part 2.

Line 3 is the buildings total allowed watts for display lighting. This value is obtained from the Total Watts entries on LTG-4, Part 2 and Part 3. Each display allotment is separately calculated and entered into the appropriate column on this form.

Line 4 is the sum of lines 1, 2, and 3. The Total Allowed Watts is the Allowed Lighting Power using the Tailored Method.

Tailored LPD- Illuminance Categories A, B, C, D and Gross Sales Floor Area

To complete the lower portion of Part 1 of this form, complete the following steps.

a. **Room Number** Column A lists the room number of space designation and should correspond with the plans.

b. **Task/Cavity** Column B lists the task or activity that will occur in the room or space.

c. **Illuminance Category** Column C lists the Illuminance Category for the room or space. This is determined by using either Table 5-5, Table B-10 of Appendix B, or the IES Handbook, Applications Volume, 1987. Additional information is included in Section 5.2.2C of this Manual.

d. **Room Cavity Ratio** Column D lists the room cavity ratio (RCR) of each room or space. A RCR of less than 3.5 may be assumed for any room. Table 5-6 in Section 5.2.2C includes the RCR of simple spaces. The LTG-5 may be used to calculate an RCR greater than or equal to 3.5.

e. **Floor Area** Column E lists the actual floor area of the room or space from the plans. The area is determined by measuring from the inside of the partitions that bound the task area.

f. **Allowed LPD** Column F lists the allowed lighting power density from Table (*Standards* Table No. 1-R) using the Illuminance Category (Column C) and room cavity ratio (Column D) for each room. For Gross Sales Floor Areas, this value can be no more than 2.0 watts per square foot.

g. **Allowed Watts** Column G is the product of the floor area, Column E times allowed lighting power density, Column G. The total for all rooms or spaces that contain task activities that fall within Illuminance Categories A through D entered in line 1 at the top of LTG-4, Part 1.

B. LTG-4 Part 2 of 3

Tailored LPD – Illuminance Categories E, F, G, H, I and Gross Sales Wall Area

To complete the upper portion of Part 2 of this form, complete the following steps.

a. **Task/Activity** Column A lists the task or activity that will occur in the room or space. Gross Sales Wall Areas do not include architectural features that prevent the use of the wall for the display of merchandise. See Section 5.2.2C for more information on how to calculate the areas of tasks or activities.

b. **Illuminance Category** Column B lists the Illuminance Category for the room or space. This is determined according to Table 5-5 of Appendix B, Table B-10, Illuminance Categories, or using the IES Handbook Application Volume, 1987. Additional information is included in Section 5.2.2C of this Manual.

c. **Room Cavity Ratio if using Category E** Column C lists the room cavity ratio (RCR) of each room or space that requires the use of Illuminance Category E. A RCR of less than 3.5 may be assumed for any room. Table 5-6 in Section 5.2.2C includes the RCRs of simple spaces. The LTG-5 may be used to calculate an RCR greater than or equal to 3.5.

d. **Mounting Height or Throw Distance** Column D lists either the mounting height, throw distance, or both (if both are used), for the luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height and throw distance of luminaires.

Allotted Watts

e. **Task Area sf** Column E lists the actual floor area of the room or space from the plans. The area is determined by measuring from the inside of the partitions, if any, that bound the task area.

f. **Column F list the allowed LPD from Table 5-7** (*Standards* Table No. 1-R) using the Illuminance Category (Column B), room cavity ratio for Illuminance Category E (Column C) rooms or spaces, and mounting height/throw distance adjustment factors (Column D) for display luminaires. For Gross Sales Wall Areas, this value can be no more than 2.0 watts per square foot.

g. **Allotted Watts** Column G is the product of the floor area times allowed LPD (Column E times Column F).

Design Watts

h. **Luminance Name** Column H lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the task or activity. If more than one luminaire type is used to illuminate the task or activity, each type must be separately listed. Multiple lines on this form may be used for this list.

i. **Quantity of Luminaries** Column I lists the quantity of luminaires used to illuminate the task or activity. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

j. **Watts/Luminaire** Column J lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

k. **Design Watts** Column K is the product of the quantity of luminaires (Column I) times the watts per luminaire (Column J). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

Decorative Chandeliers and Sconces are allowed the smaller of 20.0 watts per cubic foot, one (1) watt per square foot times the area of the task space that the chandelier or sconce is in, or the actual design wattage of the chandelier or sconce. These displays may use the Illuminance Category E through I form to determine the Allowed Lighting Power for these displays.

Enter the smaller of 20.0 watts per cubic foot of chandelier or sconce volume, or one (1) watt per square foot of area that the chandelier or sconce is in Column G. If volume is used to determine the Allotted Watts in Column G, enter the area of the task space in Column D (Notes), the volume in cubic feet in Column E and the 20.0 watts per cubic foot allotment in Column F. If area was used to determine the Allotted Watts in Column G, enter the volume in Column D (Notes), the area in Column E and one (1) watt per square foot in column F. Enter the chandelier or sconce name in Column H, the quantity in Column I and the watts per luminaire in Column J.

l. **Allowed Watts** Column L is the lesser of either the Allotted Watts (Column G) or the Design Watts (Column K).

The sum of the Allowed Watts in Column L is entered on Line 2, Part 1 of LTG-4.

Tailored Lighting - Public Area Displays

When public areas include feature display lighting, it must be documented according to the floor display lighting procedure established in Section 5.2.2C. To complete the lower portion of Part 2 of LTG-4, complete the following steps.

a. **Task Activity** Column A lists the name of the Section 5.2.2C for definition of Public Area Displays.

b. **Throw Distance** Column B lists the throw distance of the display luminaires. Section 5.2.2C contains a discussion on how to determine the throw distance of display luminaires.

c. **Mounting Height** Column C lists the mounting height for display luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height of display luminaires.

Allowed Watts

d. **Task Area sf** Column D lists the actual area of the display from the plans. This area must be totaled at the bottom of the column. Additional public display allowances cannot be taken for public displays exceeding 10 percent of the public area. Section 5.2.2C contains a discussion on how to determine the area of the display.

e. **Allowed LPD** Column E lists the allowed lighting power density from Table 5-8 using the mounting height/throw distance adjustment factors (Columns C and D) for display luminaires.

f. **Allotted Watts** Column F is the product of the task area (Column D) times allowed lighting power density (Column E.)

Design Watts

g. **Luminaire Name** Column G lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

h. **Quantity of Luminaries** Column H lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

i. **Watts/Luminaire** Column I lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

j. Design Watts Column J is the product of the quantity of luminaires (Column H) times the watts per luminaire (Column I). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

k. Allowed Watts Column K is the lesser of either the Allotted Watts (Column F) or the Design Watts (Column J).

The sum of the Allowed Watts in Column K is entered on Line 3, Part 1 of LTG-4.

C. LTG-4: Part 3 of 3

Tailored Lighting - Sales Feature Floor Displays

When retail spaces include sales feature floor display lighting, it must be documented according to the display lighting procedure established in Section 5.2.2C. An allotment of 1,000 watts is permitted for sales feature floor displays in lieu of performing this calculation, if the gross sales area of the entire building is less than 800 square feet.

Complete the upper portion of Part 3 of this LTG-4, complete the following steps.

a. Task/Activity Column A lists the name of the sales feature floor display. See Section 5.2.2C for more information on the definition of Sales Feature Floor Displays.

b. Throw Distance Column B lists the throw distance of the display luminaires. Section 5.2.2C contains a discussion on how to determine the throw distance of display luminaires.

c. Mounting Height Column C lists the mounting height for display luminaires. Section 5.2.2C contains a discussion on how to determine the mounting height of display luminaires.

Allowed Watts

d. Task Area sf Column D lists the actual floor area of the display from the plans. This area must be totaled at the bottom of the column. Additional Sales Feature Floor Display allowances cannot be taken for displays exceeding 10 percent of the gross sales floor area. Section 5.2.2C contains a discussion on how to determine the area of the Sales Feature Floor Displays.

e. Lighting Power Density if using Category G Column E lists the allowed lighting power density from Table 5-8 using the mounting height/throw distance adjustment factors (Columns C and D) for display luminaires. This allowance will always be based on Illuminance Category G.

f. Allotted Watts Column F is the product of the task area (Column D) times the Illuminance Category G lighting power density (Column E.)

Design Watts

g. Luminaire Name Column G lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

h. Quantity of Luminaire Column H lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

i. Watts/Luminaire Column I lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

j. Design Watts Column J is the product of the quantity of luminaires (Column H) times the watts per luminaire (Column I). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

k. **Allowed Watts** Column K is the lesser of either the Allotted Watts (Column F) or the Design Watts (Column J).

Valuable Merchandise Display Cases that contain jewelry and other valuable merchandise are allowed 20.0 watts per square foot for each square foot of lighted display case counter top. These displays may use the Sales Feature Floor Display form to determine the Allowed Lighting Power for these displays.

Enter the area of the lighted display case counter top in Column D, and the 20.0 watts per square foot allotment in Column E. The area should not be included in the total Sales Feature Floor Display area. Enter the luminaire name used to illuminate the lighted display counter top in Column G, the quantity in Column H, and the watts per luminaire in Column J.

Detailed documentation must be provided on the plan that shows the placement of display cases, specific dimensions, and details of proposed lighting systems.

The sum of the Allowed Watts for Sales Feature Floor Displays in Column K is entered on Line 3, Part 1 of LTG-4.

As with all applications in Illuminance Category G, the allowed lighting watts for feature displays may not exceed the actual installed wattage. This prevents unused display lighting allotments from being used in other areas of the store.

Tailored LPD - Sales Feature Wall Displays

When retail spaces include sales feature wall display lighting, it must be documented according to the display lighting procedure established in Section 5.2.2C. To complete the lower portions of this form complete the following steps. See LTG-4 part 2 of 2 lower part.

a. **Task/Activity** Column A lists the name of the sales feature wall display. See Section 5.2.2C for more information on the definition of Sales Feature Wall Displays.

b. **Throw Distance** Column B lists the throw distance of the display luminaires. Section 5.2.2Ccontains a discussion on how to determine the throw distance of display luminaires.

c. **Task Area sf** Column C lists the actual wall area of the display from the plans. This area must be totaled at the bottom of the column. Additional Sales Feature Wall Display allowances cannot be taken for displays exceeding 10 percent of the gross sales wall area. Section 5.2.2C contains a discussion on how to determine the area of the Sales Feature Wall Displays. The Gross Sales Wall Area is limited to the area actually used for display.

d. **Lighting Power Density if using Category G** Column D lists the allowed lighting power density from Table 5-8 using the mounting throw distance adjustment factors (Columns B and C) for display luminaires. This allowance will always be based on Illuminance Category G.

e. **Allowed Watts** Column E is the product of the task area (Column C) times allowed lighting power density (Column D.)

f. **Luminaire Name** Column F lists the luminaire name (consistent with LTG-1 and 2) that is illuminating the display. If more than one luminaire type is used to illuminate the display, each type must be separately listed. Multiple lines on this form may be used for this list.

g. **Quantity of Luminaire** Column G lists the quantity of luminaires used to illuminate the display. If track lighting is used, and the plans do not indicate the number of fixtures to be used on the track, the actual length of track is entered in this column.

h. **Watts/Luminaire** Column H lists the total wattage of each luminaire type (including ballasts for fluorescent or high intensity discharge fixtures). For track, and incandescent medium base socket fixtures, see Section 5.2.4 for how to determine the watts of these types of luminaires. If track lighting is used, and the fixtures are not shown on the plans, 45 watts per foot of track is entered in this column.

i. **Design Watts** Column I is the product of the quantity of luminaires (Column G) times the watts per luminaire (Column H). If more than one luminaire type is used to illuminate the task or activity, the subtotal for all the luminaires illuminating the task should be indicated in this column on a separate line of the form.

j. **Allowed Watts** Column J is the lesser of either the Allotted Watts (Column E) or the Design Watts (Column I).

The sum of the Allowed Watts for Sales Feature Wall Displays in Column J is entered on Line 3, Part 1 of LTG-4.

As with all applications in Illuminance Category G, the allowed lighting watts for feature displays may not exceed the actual installed wattage. This prevents unused display lighting allotments from being used in other areas of the store.

5.3.3 LTG-5: Room Cavity Ratio Worksheet (>3.5)

Form LTG-5 is an optional form only to be used in conjunction with the Tailored Method and form LTG-4. LTG-5 documents the calculation of room cavity ratios (RCRs) which are greater than or equal to 3.5 for spaces in illuminance categories A-E.

Rooms in the building which are relatively large generally have a high RCR. If the RCR is greater than or equal to 3.5, a higher LPD is allowed (see Table 5-7). If the RCR is less than 3.5, it does not need to be included on this form.

The form has two sections: **Rectangular Spaces** is for rooms with four 90 walls, and **Non-rectangular Spaces** is for all other room types (including oblique four walled and circular rooms).

A. Rectangular Spaces

a. **Room Number** Column A lists each rooms number, and should correspond to the plans.

b. **Task/Activity Description** Column B lists the task/activity description for the room. If the room has multiple tasks or activities, use the dominant activity for the room in this column.

c. **Room Length** Column C lists the Length (L) of the room, measured in feet, from the interior surfaces of opposing walls. The length is typically the longest distance between two parallel walls in the room.

d. **Room Width** Column D lists the Width (W) of the room, measured in feet, from the interior surfaces of opposing walls. The width is typically the smallest distance between two parallel walls in the room.

e. **Room Height** Column E lists the vertical distance, measured in feet, from the work plane to the center line of the lighting fixture. This measurement is called the Room Cavity Height (H).

f. **Room Cavity Ration** Column F is 5 times the product of the Room Cavity Height H (from Column E) and the sum of the room Length and Width L (from Column C plus W from Column D), all divided by the Room Area L (from Column C) times Room Width (W from Column D). This quantity is the RCR and should be entered in Column D of Part 1 of LTG-4 for tasks with illuminance categories A-D or in Column C of the top section of Part 2 of LTG-4 for tasks with illuminance category E.

B. Nonrectangular Spaces

a. **Room Number** Column A lists each rooms number, and should correspond with the plans.

b. **Task/Activity Description** Column B lists the area or activity description for the room. If the room has multiple tasks or activities, use the dominant activity for the room in this column.

c. **Room Area** Column C lists the interior Area (A) of the room in square feet. This should be determined by whatever means appropriate for the shape of the room.

d. **Room Perimeter** Column D lists the Room Perimeter (P) measured in feet along the interior surfaces of the walls which define the boundaries of the room. For rooms with angled walls, this is the sum of the interior lengths of each wall in the room. For circular rooms, this is the interior radius of the room, squared, times pi (3.413).

e. **Room Height** Column E lists the vertical distance, measured in feet, from the work plane to the center line of the lighting fixture. This measurement is called the Room Cavity Height (H).

f. **Room Cavity Ratio** Column F is 2.5 times the product of the Room Cavity Height H (from Column E) and Room Perimeter P (from Column D), all divided by the Room Area A (from Column C). This quantity is the RCR and should be entered in Column D of Part 1 of LTG-4 for tasks with illuminance categories A-D or in Column C of the top section of Part 2 of LTG-4 for tasks with illuminance category E.

5.4 Lighting Inspection

The electrical building inspection process for energy compliance is carried out along with the other building inspections performed by the building department. The inspector relies upon the plans and upon the LTG-1 Certificate of Compliance form printed on the plans (See Section 5.3.1). Included on the LTG-1 are “Notes to Field” that are provided by the plans examiner to alert the field inspector to items of special interest for field verification.

To assist in the inspection process, an Inspection Checklist is provided in Appendix I.

6 Special Topics

6.0 Summary

This chapter provides more complete illustrations of how the *Standards* apply to items that involve all disciplines: envelope, mechanical and lighting. This includes the performance approach, hotel/motel compliance, and high-rise residential compliance.

Section 6.1 summarizes the Performance Approach. It includes a discussion of computer methods and how compliance is shown with a computer method, the procedures involved in determining the energy budget and the proposed building's energy use, and how to plan check performance compliance. Section 6.2 is a discussion of Hotel/Motel buildings and how compliance is demonstrated for those occupancies. Section 6.3 is a discussion of High-rise Residential buildings and how compliance is demonstrated for those occupancies.

6.1 Performance Approach

6.1.1 Summary

This section explains the use of approved public domain and *Alternative Calculation Method* (ACM) computer programs to show compliance with the annual energy budget requirement of the *Standards.* The computer methods represent one of the basic compliance paths explained in Chapter 1.

Performance Concepts (Section 6.1.2) outlines the basis of the computer method approach and the ACM approval process for the use of a computer program with the *Standards.* The following section summarizes the compliance procedure with computer methods.

Section 6.1.2 describes the concepts and procedures involved in using the performance approach. Section 6.1.3 describes analysis procedures used to demonstrate compliance, including the rules used to generate the annual energy budget. Section 6.1.4 outlines and illustrates the plan check documents required when using the performance approach.

Note**:** This chapter should not be construed as a substitute for the compliance supplement of any particular approved computer program.

6.1.2 Performance Concepts

The Warren-Alquist Act calls for the establishing "performance standards" that predict and compare the source energy use of buildings. Because of their relative accuracy in analyzing the annual energy use of different building efficiency measures, computer programs are the basis of the performance standards.

A computer program (alternative calculation method (ACM)) cannot be used for demonstrating compliance with the *Standards* unless the ACM, the capability tests, and the vendor's certification are reviewed and approved by the *Energy Commission*. The programs simulate or model the thermal behavior of buildings and the interaction of their space conditioning, lighting and service water heating systems. The calculations include:

Heat gain and heat loss through walls, roof/ceilings, floors, windows, and skylights.

Solar gain from windows, skylights, and opaque surfaces.

Heat storage effects of different types of thermal mass.

Building operating schedules for people, lighting, equipment and ventilation.

Space conditioning system operation including equipment part load performance.

The prescriptive requirements were derived from the results of building energy analysis studies using the reference computer program, DOE.

Computer methods are generally the most detailed and flexible compliance path. The energy performance of a proposed building design can be calculated according to actual building geometry and site placement. Credit for certain conservation features, such as a daylit atrium, cannot be taken in the prescriptive approach, but could be evaluated with an approved computer program.

A. Approval of Computer Programs

For any computer program (alternative calculation method) to be used for compliance with the *Standards*, the program must first be approved by the *Energy Commission*. Approval involves the demonstration of minimum modeling capabilities, required input and output, and adequate user documentation. The program must be able to:

Automatically calculate the custom energy budget.

Calculate the energy use of the proposed design in accordance with specific fixed and restricted inputs.

Print the appropriate standardized compliance forms with the required information and format if and only if a proposed building complies. Other reports that do not resemble forms may be printed for noncomplying buildings.

Input and output requirements and modeling capabilities are tested by using the program to calculate the energy use of certain prototype buildings under specific conditions, and the results are compared with the results from a reference computer program following the specified reference methodology. These tests and testing criteria do not allow the approval of an ACM that indicates compliance for a building that the reference method indicates does not comply with the *Standards*.

The *Energy Commission* approves the alternative calculation method according to the procedures outlined in §10-104 and 10-110 of the *California Code of Regulations*, Title 24, Part 1. The procedures are detailed in the *Alternative Calculation Methods Approval Manual for the Energy Efficiency Standards for Nonresidential Buildings, High-rise Residential Buildings and Hotel/Motels (ACM Approval Manual).* The *Energy Commission* periodically updates a listing of approved computer programs that may be obtained from the Publications Office, by calling the *Energy Commission*'s Hotline at 1-800-772-3300, or by accessing the *Energy Commission*'s Web Site (www.energy.ca.gov/efficiency).

B. The Energy Budget

The energy budget that a building must comply with is composed of three basic components: space conditioning, lighting, and water heating. Space conditioning is further broken into space heating, space cooling, HVAC fans and pumps, and receptacle. It is expressed in source Btu per square foot of conditioned floor area per year (*Standards* §141(b)).

A building complies with the *Standard* if the predicted source *energy use* of the proposed design is the same or less than the annual *energy budget* of the standard design. The energy budget includes a space conditioning budget, lighting budget and water heating budget. The budget for space conditioning varies according to specific characteristics of the proposed building design outlined below.

The energy budget is dependent on how a building is oriented, and the budget will vary with actual building orientation. Other variables that affect the energy budget include:

- Conditioned floor area
- Conditioned volume
- Gross exterior surface area
- Space conditioning system type
- Occupancy type
- Climate zone

Assumptions used by the computer programs in generating the energy budget are explained in detail in the *ACM Approval Manual* , but are based on the prescriptive requirements of the *Standards.* The standard lighting power density for the building is determined by the program based on occupancy type, in accordance with the Complete Building, Area Category, and Tailored rules described in Section 5.2.2.

The Standard Design and Proposed Design for a building is summarized in an Annual Source Energy Use Summary on the PERF-1: Performance Certificate of Compliance form, described in Section 6.1.4 and illustrated in Figure 6-1. The Standard Design is calculated according to the rules and assumptions in the *ACM Approval Manual,* and represents the total allowable energy budget for the building. The Proposed Design must be equal to or less than that of the energy budget for the building to comply.

Figure 6-1– Annual Source Energy Use Summary (Sample of PERF-1, Part 2 of 3)

ANNUAL SOURCE ENERGY USE SUMMARY (kBtu/sf-yr)			
ENERGY USE BY COMPONENT	STANDARD DESIGN	PROPOSED DESIGN	COMPLIANCE MARGIN
SPACE HEATING			
SPACE COOLING			
FANS/PUMPS			
LIGHTS			
WATER HEATING			
RECEPTACLE			
TOTAL			

C. Compliance With a Computer Method

Each approved computer program automatically generates an *energy budget* by calculating the annual energy use of the standard design, a version of the proposed building incorporating all the prescriptive features.

Although any single component of the energy use may be higher than the equivalent component in the energy budget, the total combined energy use of the Proposed Design must be less than or equal to the Standard Design. This way, trade-offs can be made between space conditioning, lighting and service water heating energy use. See Section 6.1.2E for restrictions of trade-offs.

Example 6-1– Performance Trade-offs

Question

If a PERF-1 (see Figure 6-1) shows that the proposed energy use of the “HVAC Fans and Pumps” exceeds the standard design energy budget, but the total energy use is less than the energy budget, does the building still comply?

Answer

Yes. More fan energy is being used by the proposed design, but the “Total” proposed energy use is less than the “Total” standard design energy budget, therefore the building complies.

D. Compliance Procedure

Any approved computer program may be used to comply with the *Standards.* The following steps are a general outline of the typical compliance procedure:

1. All detailed data for the building component or components must be collected including glazing, wall, door, roof/ceiling, and floor areas, construction assemblies, shading coefficients, mass characteristics, equipment specifications, lighting, and service water heating information from the drawings and specifications. Section 6.1.3B contains more detailed information on the required computer program inputs.

Although most computer programs require the same basic data, some information, and the manner in which it is organized, may vary according to the particular program used. *Refer to the compliance supplement that comes with each program for additional details.*

Be sure that the correct climate zone has been selected for the building site location (see Appendix C).

2. The program user has the option of using default U-factors based on the tables contained in Appendix B, Table B-7. If default U-factors for wall, roof/ceiling, and floor/soffit are not used, prepare the appropriate ENV-3 forms for the various proposed construction assemblies either through the use of the program or by a hand calculation.

3. Prepare an input file that describes the other thermal aspects of the proposed design according to the rules described in the program’s compliance supplement.

Input values and assumptions must correctly correspond to the proposed design and conform to the required mandatory measures described in Chapters 3, 4 and 5.

4. Run the computer program to automatically generate the energy budget of the standard design and calculate the energy use of the proposed design.

The building complies if the total energy use of the proposed design is the same or less than the standard design energy budget.

Note: When creating any computer input file, use the space provided for the project title information to concisely and uniquely describe the building being modeled. User-designated names should be clear and internally consistent with other buildings being analyzed in the same project. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement process.

E. Application Scenarios

Compliance with the performance approach can be done whenever compliance is demonstrated for each permit application. Each application for permit can be either a prescriptive or performance application. Because of this, the following procedures are developed in the *ACM Approval Manual* to limit the use of historical documentation.

Whole Building Compliance

Whole buildings are projects involving buildings where the applicant is applying for permits, and submits plans and specifications for all the features of the building (envelope, mechanical, lighting and service water heating). This could be a first time tenant improvement that involves envelope, mechanical and lighting compliance, or a complete building, where plans and specifications for the entire building are being submitted for permit.

When a whole building is modeled using the performance approach, trade-offs can be made between the envelope, space conditioning, service water heating, and lighting systems that are included in the permit application.

Compliance by Permit Stage

Compliance with only one or more building *permit stages* can be done using the performance approach. A *permit stage* is a portion of a whole building permit: either envelope, mechanical, or electrical. *Standards* §141(b) states that only the features of the building that are included in the building permit application can be modeled. This means that trade-offs in energy use are limited to include only those features included in the building permit application.

There are two basic scenarios that occur when performing compliance by permit stage: modeling *future construction* features that are not included in the permit application, and modeling *existing construction* that has complied with the *Standards.*

Modeling Future Construction by Permit Stage

When a feature of a building is not included in the permit application, it is required to *default* to a feature automatically determined in the computer program. The defaults vary for envelope, mechanical, and lighting. The *ACM Approval Manual* contains additional information on the default values.

The *default envelope features* do not apply when modeling future construction. Usually, this is the first permit requested and at a minimum this feature must be modeled. The proposed building's envelope features are input and an energy budget is automatically generated based on the proposed building's envelope, and/or space conditioning and lighting system.

The *default space conditioning system* features are fixed if no space conditioning system exists in the building. A standard package gas/electric unit is assumed for each thermal zone in the proposed design. The package system is sized based on the envelope design and it meets the prescriptive requirements. If a space conditioning system is included in the permit application, the default space conditioning system is based on the standard design as determined in the *ACM Approval Manual*.

The *default service water heating system* features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type.

The *default lighting system* features depend on whether or not the occupancy of the building is known. If the building occupancy is known, the Allowed Lighting Power Density is determined using the Complete Building Approach for each zone that the occupancy is known. If the building occupancy is not known, 1.2 watts per square foot is assumed for both the proposed energy use and the energy budget.

Modeling Existing Construction by Permit Stage

When a feature of a building is not included in the permit application, and it is an existing building feature, it is required to *default* to a feature automatically determined in the computer program. The defaults vary for envelope, mechanical, and lighting. The *ACM Approval Manual* contains additional information on the default values.

The *default envelope* features are based on the program user's inputs to the computer program. The proposed building's conditioned floor area, glazing, wall, floor/soffit, roof/ceiling, and display perimeter features are input by the program user. The computer program then applies the proposed building's features to the standard design in order to calculate the energy budget. This means that if an application for an envelope permit is not being sought , the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. Only the EXISTING-ENV will be printed to document the existing building.

The *default space conditioning system* features are fixed based on the building's existing space conditioning system. The program user inputs the existing space conditioning system, including actual sizes and types of equipment. The computer program then applies the proposed building's space conditioning features to the standard design in order to calculate the energy budget. This means that if an application is not being sought for a mechanical permit, the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. No mechanical forms will be printed.

The *default service water heating system* features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type. Water heating information will only be listed as "existing".

The default lighting system features are based on the known occupancy of the building. The Allowed Lighting Power Density is determined based on the Actual Lighting Power Density of the building. The computer program then applies the proposed building's features to the standard design in order to calculate the energy budget. This means that if an application for a lighting permit is not being sought, the computer program will automatically default the features of the standard design to be the same as the features of the proposed design. No LTG form will be printed. All reported lighting will be reported on the PERF-1 Performance Certificate of Compliance.

Additions Performance Compliance

An addition is treated similar to a new building in the performance approach. Since both new conditioned floor area and volume are created with an addition, all systems serving the addition will require compliance to be demonstrated. This means that either the prescriptive or performance approach can be used for each stage of the construction of the addition.

NOTE: When existing space conditioning or water heating is extended from the existing building to serve the addition, those systems do not need to comply.

Addition Only

Additions that show compliance with the performance approach, independent of the existing building, must meet the requirements for new buildings. *Standards* §149(a)2 states that the envelope and lighting of the addition, and any newly installed space conditioning or service water heating system serving the addition, must meet the mandatory measures and the energy budget determined in the performance run.

If the permit is done in stages, the rules for each permit stage apply to the addition performance run.

If the whole addition is included in the permit application, the rules for whole buildings apply.

Existing plus Addition

Additions may also show compliance by *either* 1) demonstrating that efficiency improvements to the envelope component of the existing building, offset decreased addition performance (see §149(a)2.B.2.), or 2) that the existing building combined with the addition meets the present *Standards* (per §149(b). *Standards* §149(a)2 states that the envelope and lighting of the addition, and any newly installed space conditioning or service water heating system serving the addition, must meet the mandatory measures just as if it was an addition only. It also allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building, if the existing building was unchanged, and the addition complied on its own. Note that improvements refer to 'improvements over existing building' and not to improvements over default envelope features.

It is important to note that the term entire building means the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all conditioned and unconditioned space within the structure.

To show compliance with this approach you need to follow the instructions in the computer program's compliance supplement.

When using this compliance approach it is important to take into account all changes in the building's features that are removed from or added to the existing building.

Documentation of the existing building's features is required to be submitted with the permit application if this method is used.

Alterations Performance Compliance

Using the performance approach for an alteration is similar to demonstrating compliance with an addition.

Alteration Only

Altered spaces can show compliance with the performance approach independent of the existing building, and must meet the requirements for new buildings. *Standards* §149(b)2 states that the envelope and lighting of the alteration, and any newly installed space conditioning or service water heating system serving the alteration, must meet the mandatory measures and the permitted space alone shall comply with the energy budget determined using an alternative computer program.
If the permit is done in stages, the rules for each permit stage apply to the alteration performance run.

Existing Buildings with Whole Building Approach Alteration

Alterations may also show compliance by demonstrating that efficiency improvements to the existing building offset decreased performance of the permitted space. *Standards* §149(a)2 states that envelope, lighting, space conditioning or service water heating system alterations, must meet the mandatory measures. This approach allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building if the existing building was unchanged, and the permitted space complied on its own.

To show compliance with this approach you need to follow the instructions in the computer program's compliance supplement.

When using this compliance approach it is important to take into account all changes in the building's features that are removed from or added to the existing building as a part of the alteration.

Documentation of the existing buildings features is required to be submitted with the permit application if this method is used. An EXISTING-ENV report must be presented.

Alternate Performance Compliance Approach

Any addition, alteration or repair may demonstrate compliance by meeting the requirements applicable to new buildings for the entire building. Using this method, the entire building could be shown to comply in permit stages or as a whole building. The rules for new buildings, permit stage compliance, and whole building compliance would apply.

Documentation of the existing buildings features is required to be submitted with the permit application if this method is used.

F. Professional Judgment

As explained in the next section, certain modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. That is, there is little or no freedom to choose input values regarding specific input variables for compliance modeling purposes. However, there remain other aspects of computer modeling for which professional judgment is necessary. In those instances, it must be exercised properly in evaluating whether a given assumption is appropriate.

Building departments have full discretion to question the appropriateness of a particular input, especially if the user has not substantiated the value with supporting documentation.

Two questions may be asked in order to resolve whether good judgment has been applied in any particular case:

- Is the approach or assumption used in modeling the proposed design consistent with the approach or assumption used in generating the energy budget?

The rule is to model the proposed design using the same assumption and/or technique used by the program in calculating the energy budget unless drawings and specifications indicate specific differences that warrant conservation credits or penalties.

- Is a simplifying assumption appropriate for a specific case?

- If simplification reduces the energy use of the proposed building when compared to a more explicit and detailed modeling assumption, the simplification is not acceptable.

6.1.3 Analysis Procedures

This section is a summary of the analysis procedures used in demonstrating compliance with approved computer programs. It describes the procedures specified in §141 of the *Standards. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program*.

Although there are numerous requirements for each ACM input, the data entered into each approved computer program may be organized differently from one program to the next. As a result, it is not possible in this summary to present all variables in their correct order or hierarchy for any one program. The aim is simply to identify the procedures used to calculate the standard design energy budget and the source energy use of the proposed building.

A. Energy Budget

The energy budget consists of three main components: the space conditioning energy budget, the lighting budget, and the service water heating budget. These components are discussed in §141(a)1, 2 and 3 of the *Standards.*

Space Conditioning Energy Budget

The space conditioning budget is defined in *Standards* §141(a)1 as "... the source energy used for space conditioning in a standard building in the Climate Zone in which the proposed building is located, calculated with a method approved by the Commission...." The space conditioning energy budget is automatically determined from the program user's inputs from the corresponding elements of the proposed design. This budget is automatically re-calculated each time a compliance run is done.

The space conditioning energy budget consists of the elements described in the *ACM Approval Manual.*

Lighting Energy Budget

The lighting energy budget is defined in the *Standards* §141(a)2 as "...the source energy used for lighting in a standard building calculated with a method approved by the Commission..." The budget consists of the lighting power used by a building based on one of the following criteria:

- When no lighting plans or specifications are submitted for permit, and the occupancy of the building is not known, the standard lighting power density is 1.2 watts per square foot.

- When no lighting plans or specifications are submitted for permit and the occupancy of the building is known, the *standard lighting power density* is equal to the corresponding watt per square foot value derived in the Complete Building Method (*Standards* §146(b)1*)*.

- When lighting plans and specifications are submitted for permit, the standard and proposed lighting power density is equal to the corresponding total allowed lighting power (in watts) calculated using either the Complete Building Method, the Area Category Method, or the Tailored Method (*Standards* §146(b)1, 2 or 3). A complete set of lighting plans and prescriptive forms are required for use of the Tailored Lighting Method in the performance approach. The ACM calculated lighting power must always be within 2% of the lighting power calculated by the performance approach.

The *Standards* only allow lighting trade-offs against the allowed watts per square foot based on actual occupancy (general lighting categories A through D). Submitted lighting plans must show lighting loads equal to or less than on the energy documentation.

Service Water Heating Energy Budget

The service water heating energy budget is defined in the *Standards* §141(a)3 as "...the source energy used for service water heating in a standard building calculated in the Climate Zone in which the proposed building is located, calculated with a method approved by the Commission...." The budget consists of the service water heating energy used by a building assuming the service water heating system meets both the mandatory and prescriptive requirements as described in Section 4.2.1J and 4.2.2J of this *Manual* (*Standards* §111, §113 and §123).

B. Source Energy Use

The source energy use consists of three main components; the space conditioning energy use, the lighting energy use, and the service water heating energy use. These components are discussed in §141(b)1, 2, and 3 of the *Standards.*

The key component of calculating the source energy use of the proposed building is that if a feature of the building is not included in the building permit application, the energy use of that feature is equal to that of the standard energy budget (*Standards* §141(b)). That means that if a permit is submitted for a shell building (envelope only), and the performance approach is used to demonstrate compliance, trade-offs cannot be made between the envelope and the mechanical or lighting system.

Space Conditioning Source Energy Use

The space conditioning source energy use must be calculated using a method approved by the *Energy Commission*. The following elements are used by the approved computer programs. These elements must be consistent with plans and specifications submitted in the building permit application:

Gross Exterior Surfaces: All gross exterior surfaces, each with its respective area, orientation and tilt.

Opaque Exterior Walls: Each opaque exterior wall construction assembly, as well as wall area, orientation and tilt. Heat capacities, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior walls, must be included.

Doors: All doors must be included.

Opaque Roofs/Ceilings: Each opaque exterior roof/ceiling construction assembly, as well as roof/ceiling area, orientation and tilt. Heat capacity, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior roof/ceilings, must be included.

Raised Floors and Slab Floors: Each floor construction assembly, as well as floor area.

Glass in Walls and Shading: Each vertical glass area, orientation, tilt, U-factor and shading coefficient.

Horizontal (Skylight) Glass and Shading: Each horizontal or skylight glass area, orientation, tilt, U-factor and shading coefficient.

Ventilation (Outside) Air: Ventilation (or outside air) values in cfm/ft^2 .

Fan Power: Fan power must be included.

Cooling and Heating Efficiency: The actual efficiency of the equipment included in the proposed design.

No Heating or Cooling Installed: If total heating or cooling capacity is not specified, the source energy use will be based on a standard design heating or cooling system (*Standards* §141(b)).

Cooling System Capacity: Sensible output capacity of the cooling system at ARI conditions.

Heating System Capacity: The output capacity of the heating system.

Other System Values: All other space conditioning system components that are used by approved computer programs.

Refer to the *ACM Approval Manual* for more detailed information on how each of the above values are used by the computer programs.

Lighting Source Energy Use The lighting source energy use is calculated using a method approved by the *Energy Commission*. When plans and specifications are submitted for permit, the lighting source energy use is calculated using the following elements:

Proposed Lighting Power Density: For all occupancies except Hotel Guest Rooms and High-rise residential living quarters, the proposed lighting power density, in watts per square foot (*Standards* §141(a)2).

For residential occupancies (Hotel Guest Rooms or High-rise Residential Buildings), the approved computer program will always fix the proposed lighting power density at the values listed in the *ACM Approval Manual.*

Service Water Heating Source Energy Use The service water heating source energy use is calculated using a method approved by the *Energy Commission*. It is calculated using a method described in the *ACM Approval Manual* using the proposed building service water heating system. This system must be consistent with plans and specifications submitted in the building permit application

6.1.4 Performance Plan Check Documents

At the time a building permit application is submitted to the building department, the applicant also submits plans and energy compliance documentation. This section describes the forms and procedures for documenting compliance with the performance requirements of the *Standards* when an Alternative Calculation Method (ACM), typically a computer program, is used to demonstrate compliance. The *ACM Approval Manual* has specific and detailed output/reporting requirements for all approved ACMs. The administrative regulations require certain specific forms and only those forms for a particular type of compliance by referencing the *ACM Approval Manual* requirements.

ACM compliance output is required to specify the run initiation time, a unique runcode, and the total number of pages of forms printed for each proposed building run whenever a building complies with the *Standards* and compliance output has been selected. The plan checker is strongly encouraged to verify these output features for a performance compliance submittal to ensure that the submittal is a consistent set of compliance documentation. The *ACM Approval Manual* forbids an ACM from printing standard compliance forms for a proposed building design that does not comply. The plan checker should pay special attention to the PERF-1 form and the Exceptional Conditions List on Part 2 of that form. Every item on the Exceptional Conditions List deserves special attention and requires additional documentation such as manufacturer's cut sheets or special features on the plans and in the building specifications.

The ACM requirements will automatically produce and reiterate the proper set of forms that correspond to the particular proposed building submitted for a permit, but the plan checker should verify the type of compliance and the required forms from the lists below. Whenever an existing building (or building components) is involved in compliance, the plan checker should look for an EXISTING form that documents EXISTING building components. Similarly if the compliance indicates existing components - partial permit compliance, addition, addition plus existing building, or any alteration, an EXISTING form must be submitted. In the types of permit applications where some building components are unknown the unknown components cannot be entered by the user and cannot be reported on output forms.

This section does not describe the details of the performance approach; these are reviewed in Section 6.1.1 and 6.1.2, in the computer program vendors' compliance supplements, and in the *ACM Approval Manual*. The following discussion is addressed primarily to the building department plan checkers who are examining documents submitted to demonstrate compliance with the *Standards*, and to the designer preparing construction documents and compliance documentation.

Most compliance forms associated with the computer method approach are generated automatically. These reports are similar in information content and layout to their prescriptive method counterparts. The main difference is appearance because computer method forms are designed to be reproducible using a dot matrix printer.

The following summary identifies the forms that are required for performance compliance. All submittals must contain the following information:

- Unless minimal efficiency and default capacities are used in the performance analysis, either equipment cut sheets showing rated capacities, fan bhp, and air flow at ARI conditions, or the installation certificate must be provided.
- Other documentation supporting each non-standard or non-default value used in the performance approach and indicated in the Exceptional Conditions list on the PERF-1 form must also be included.

Other reports that may be generated by a program are:

- ENV-3: Construction Assemblies
- Formatted Copy of Input

The following computer generated forms are required by the *ACM Approval Manual* for a permit application:

Whole Building Compliance (the number of parts is the minimum number of pages)

- PERF-1: Performance Certificate of Compliance (3 parts)
- ENV-1: Envelope Compliance Summary (1 part)
- MECH-1: Mechanical Compliance Summary (2 parts)
- MECH-2: Mechanical Equipment Summary (2 parts)
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation (1 part)
- LTG-1: Lighting Compliance Summary (1 part)

The LTG-3 (Lighting Controls Credit Worksheet) and LTG-4 (Tailored LPD Summary and Worksheet) forms may be, and typically will be, submitted by hand. When these pages are hand submitted or submitted independently, they will not be included in the page count automatically generated by the computer for a compliance submittal.

Note: The use of the tailored lighting approach requires independent prescriptive compliance for the lighting system.

Compliance By Permit Stage (the number of form parts are the same as indicated above at Whole Building Compliance)

A. Envelope Only

- PERF-1: Performance Certificate of Compliance
- ENV-1: Envelope Compliance Summary
- ENV-3: Construction Assemblies
- Possibly existing LTG and existing MECH forms: (for partial compliance alteration)

B. Envelope and Mechanical

- PERF-1: Performance Certificate of Compliance
- ENV-1: Envelope Compliance Summary
- MECH-1: Mechanical Compliance Summary

- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- Possibly existing LTG forms: (for partial compliance alteration)

C. Mechanical Only

- PERF-1: Performance Certificate of Compliance
- MECH-1: Mechanical Compliance Summary
- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- Possibly existing ENV and/or existing LTG forms: (for partial compliance alteration)

D. Mechanical and Lighting

- PERF-1: Performance Certificate of Compliance
- MECH-1: Mechanical Compliance Summary
- MECH-2: Mechanical Equipment Summary
- MECH-3: Mechanical Compliance Summary/Mechanical Ventilation
- LTG-1: Lighting Compliance Summary
- LTG-3: Lighting Controls Credit Worksheet (if control credits used)
- LTG-4: Tailored LPD Summary and Worksheet (if tailored lighting used)
- Possibly existing ENV forms: (for partial compliance alteration)

E. Lighting Only

- PERF-1: Performance Certificate of Compliance
- LTG-1: Lighting Compliance Summary
- LTG-3: Lighting Controls Credit Worksheet (if control credits used)
- LTG-4: Tailored LPD Summary and Worksheet (if tailored lighting used)
- Possibly existing ENV and existing MECH forms: (for partial compliance alteration)

Consult the computer program's compliance supplement for a detailed summary of what additional documentation may need to be included in the permit application along with the automatically-generated compliance documentation.

F. PERF-1: Performance Certificate of Compliance

The PERF-1 incorporates the first parts of the prescriptive ENV-1, LTG-1, and MECH-1 on the first part or first page. This is a combined signature document for the certificate of compliance that documents the party(ies) who has primary responsibility for the design of the envelope, lighting and mechanical systems of the building. The total Btu/ft^2 /yr for the standard design energy budget must be equal to or greater than the proposed design's energy use.

The signature statement is to certify that the documentation author correctly represented the building in the performance program.

The PERF-1 form must appear on the plans (usually near the front of the architectural drawings). A copy of this form should also be submitted to the building department along with the rest of the compliance submittal at the time of building permit application. This form must be generated by an approved alternative computer program.

G. ENV-1: Envelope Compliance Summary

The performance ENV-1 Certificate of Compliance form has one part. It summarizes the opaque surfaces including surface type, construction type, area, azimuth, and U-factor . Next it summarizes the fenestration surfaces including fenestration type, area, azimuth, U-factor, frame type and solar heat gain coefficient. Lastly, it includes exterior shading and overhangs including shade type, solar heat gain coefficient, overhang height and overhang width.

For a description of the information contained on the ENV-1 Certificate of Compliance, see ENV-1, Part 2 of 2, Section 3.3.1.

H. ENV-3: Construction Assemblies

This form is identical to the form required in the prescriptive approach and is described in Section 3.3.4, 3.3.5, and 3.3.6.

I. EXISTING-ENV: Performance Method Only

The ENV-E Performance Method form is used to identify a space. The intention of this form is to be used only in cases where the envelope has complied previously and compliance is now being sought for lighting, mechanical or both. The form includes address, date envelope complied, space name, occupancy, floor area, and volume. The form also identifies opaque surface areas and U-factors as well as glazing surface areas, U-factors, and shading coefficients.

J. MECH-1: Certificate of Compliance

The MECH-1 Certificate of Compliance form is in two parts. This form identifies the system features, duct insulation and pipe insulation that will be verified by the field inspector.

For a description of the information contained on the MECH-1 Certificate of Compliance, see Section 4.3.1 and consult the computer program's compliance supplement.

K. MECH-2: Mechanical Equipment Summary

The MECH-2 Mechanical Equipment Summary identifies the mechanical equipment modeled in the alternative computer program to show compliance. The form contains the information of the equipment name, type, number of pieces, efficiency and size, and is broken down by plant equipment (chillers, boilers, VAV, etc.) and exhaust fans.

For more information on the MECH-2, see Section 4.3.2 refer to computer program’s compliance supplement.

L. MECH-3: Mechanical Ventilation

The MECH-3 Mechanical Ventilation contains the information on the design outdoor ventilation rate for each space. Refer to the discussion in Section 4.3.3, and the computer program’s compliance supplement for more information.

M. LTG-1: Certificate of Compliance

The LTG-1 Certificate of Compliance is a multiple part form. It is used to describe the lighting fixtures and control devices designed to be installed in the building.

For a description of the information contained on the LTG- Certificate of Compliance , see LTG-1, Part 1-3 in Section 5.3.1.

If control credits were input by the program user, a copy of the LTG-3 must accompany the permit application. If the Tailored LPD was used, a copy of the LTG-4 must accompany the permit application along with a complete set of lighting plans and specifications.

6.1.5 Performance Inspection

Performance approach inspection is identical to other inspections required by the *Standards.* For information on inspection envelope, mechanical and lighting systems, see the field inspection checklist and inspection instructions, which can be found in Appendix I of this manual.

When tailored lighting is used to justify increases in the lighting load, a lower lighting load cannot be modeled for credit. The standard design building uses the lesser of allowed watts per square foot or actual lighting power to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on the lighting plans. This value must be equal to or greater than the allowed watts per square foot.

6.2 Hotels and Motels

6.2.1 Introduction

This section discusses the requirements of the *Standards* as they apply to hotels and motels. It addresses both the similarities and differences between showing compliance for a hotel/ motel and any other nonresidential or high-rise residential building. Additional information is presented regarding documenting special situations in hotel/motel compliance, and plan checking.

The design of a hotel or motel is unique in that the design must incorporate a wide variety of occupancies and functions into one structure. The occupancies range from nonresidential occupancies to hotel/motel guest rooms. Design functions that affect guests range from the "experience of arrival" created through the main lobby's architectural features to the thermal comfort of the guest rooms. Other functions that hotel/motel designs must address include restaurants, kitchens, laundry, storage, light assembly, and other items that are necessary to the hotel/motel function. In short, these structures can range from simple guest rooms with a small office, to a structure encompassing a small city.

The following sections discuss how they comply with the *Standards*.

6.2.2 Hotel/Motel Compliance Approaches

The *Standards* treat hotels/motels similarly to other occupancies: compliance is submitted for the features covered in the permit application only. Occupancy type is considered in two cases: Nonresidential portions of hotel/motels and guest room portions of hotels/motels. The nonresidential areas of hotels/motels must meet the envelope, mechanical, and lighting portions of the *Energy Efficiency Standard for Nonresidential Buildings*, and the guest room portions of hotels/motels must meet the envelope, mechanical and lighting provisions applicable only to hotels/motel guest rooms. In essence, each occupancy individually complies with the provisions applicable to that occupancy.

6.2.3 Basic Hotel/Motel Concepts

Since hotel/motels are treated as a mixture of occupancies covered by the *Standards*, the concepts presented at the beginning of each chapter apply equally to hotels/motels as they would any other nonresidential occupancy. Special cases where hotels/motel concepts are discussed include the following:

- Section 2.2.1A discusses occupancies that are covered by the *Standards.* This includes the definition of hotels/motels and a discussion of how to determine whether a building is a hotel/motel, high-rise residential, or low-rise residential.
- Section 5.1.1B includes a list of occupancy types that may be used to determine the lighting power density. The full definitions of these occupancies are included in Appendix G.

6.2.4 Hotel/Motel Compliance

The following subsections discuss the special compliance requirements that apply to hotel/motel occupancies.

A. Mandatory Measures

The mandatory measures for envelope, mechanical and lighting, as described in Sections 3.2.1, 4.2.1 and 5.2.1, apply to hotels/motels.

In addition, a special requirement applies to the lighting in hotel/motel guest rooms. This requirement states that 90 percent of the hotel/motel guest rooms must meet bathroom and kitchen lighting requirements, if any that apply to low-rise residential buildings. An explanation of this requirement is included in Appendix H.

Exceptions: The following exceptions to mandatory measures are specific to hotel/motels:

Envelope

- Manufactured fenestration products installed in hotel/motel guest rooms must be certified as meeting the nonresidential values for both air infiltration and fenestration U-factor. If default U-factors are used, they shall be consistent with the default values contained in Section 3.1.2l. If an NFRC certified fenestration product is used, the U-factor for commercial size categories shall be used.

Mechanical

- Hotel and motel guest room thermostats shall have numeric temperature settings. Section 4.2.1l contains an explanation of these requirements.
- Process loads in hotels and motels are discussed in Section 4.2.1l. Process loads in hotels/motels are treated similar to any other nonresidential building.

Lighting

- Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.
- Automatic shut-off controls are not required for hotel/motel guest rooms.

Following are examples of the noteblocks that should be rewritten to actual conditions. A noteblock for each of the items listed should be included, even if the noteblock states "not applicable".
Note: Guestrooms in hotel/motel buildings must comply with the following mandatory measures, per Title 24 §122(c) and 130(b). When this noteblock is incorporated into the permit documents or building plans, the applicable features noted shall be considered by all parties as binding minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents. This noteblock does not include nonresidential mandatory envelope, lighting, and mechanical mandatory measures, which are also applicable to Hotel/Motel buildings. See 3.2.1, 4.2.1, 5.2.1, and 6.2.4 for more examples of noteblocks for nonresidential mandatory measures.

Example 6-2 - Sample Notes: For Hotel and Motel Mandatory Measures

HOTEL/MOTEL GUEST ROOM SPACE CONDITIONING SYSTEM MEASURE
Thermostat Setpoints

Equipped with numeric temperature setpoints in ^{0}F and setpoint stops accessible only to authorized personnel, to restrict over-heating and over cooling. §122(c)

HOTEL/MOTEL GUEST ROOM LIGHTING MEASURE
Lighting

40 lumens/watt or greater for general lighting in kitchens and rooms with water closets; and recessed ceiling fixtures that are IC (insulating cover) approved. §130(b)

B. Prescriptive Compliance

The prescriptive requirements for envelope, mechanical and lighting, as described in Sections 3.2.2, 4.2.2, 5.2.2 and 6.2 apply to hotel/motels.

The following prescriptive requirements are specific to hotel/motels:

Envelope

- Special requirements apply to the envelope in hotel/motel guest rooms. These requirements state that the envelope must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings. An explanation of this requirement is included in Sections 3.2.2.

Mechanical

• Hotel and motel guest rooms are not required to have economizer controls. Section 4.2.2F contains an explanation of these requirements.

Lighting

• Guest rooms in hotel/motels are exempt from the lighting power density requirements. Section 5.2.4A contains a discussion of exempt lighting.

• Each occupancy (other than guest rooms) in the hotel/motel must comply with either the Area Category Method or the Tailored Method. The Complete Building Method may not be used. These methods cannot be mixed within a permit application. See Section 5.2.2 for a more complete discussion of how to use these compliance approaches.

C. Performance Compliance

The rules for performance compliance are identical to the rules for complying all other nonresidential and high-rise residential buildings. The area of each function of a hotel/motel is input into the program along with its corresponding envelope, mechanical and lighting features. The computer program will automatically calculate an energy budget for the standard design, and the proposed design's energy use.

A complete discussion of the performance approach is included in Section 6.1.

6.2.5 Hotel/Motel Plan Check Documents

Documenting compliance with the S*tandards* is similar to complying other nonresidential or high-rise residential buildings. The forms, and instructions for completing the forms, are included in Sections 3.3, 4.3, 5.3 and 6.1.4 of this manual. Exempt lighting, including guest room lighting, does not have to be listed on the LTG-1, or LTG-4 tailored forms, but should be clearly identified on the plans.

6.2.6 Hotel/Motel Inspection

Inspecting for compliance with the *Standards* is similar to complying other nonresidential or high-rise residential buildings. The field inspection checklist and inspection instructions can be found in Appendix I of this manual.

6.3 High-rise Residential

6.3.1 Introduction

This section discusses the requirements of the *Standards* as they apply to high-rise residential buildings. It addresses both the similarities and differences between showing compliance for a high-rise residential building and any other nonresidential building. Additional information is presented regarding documenting special situations in high-rise residential compliance, plan checking, and field inspection.

The design of a high-rise residential building must incorporate the envelope and mechanical elements of a nonresidential building, with the lighting and service hot water needs of residential buildings. The *Standards* address these features of high-rise residential buildings as described below.

6.3.2 High-rise Residential Compliance Approaches

The *Standards* treat high-rise residential buildings similar to any other occupancy: compliance is submitted for the features covered in the permit application only. Occupancy type is considered in two cases: Portions of high-rise residential buildings that are considered living quarters, and all other portions of the building. Living quarters are those non-public portions of the building in which a resident lives. The nonresidential areas of high-rise residential buildings are all other areas.

The nonresidential areas must meet the lighting portions of the *Energy Efficiency Standard for Nonresidential Buildings*, and the living quarters must meet the lighting and service water heating provisions applicable only to high-rise residential living quarters.

6.3.3 Basic High-rise Residential Concepts

The concepts presented at the beginning of each chapter apply equally to high-rise residences as they would any other nonresidential occupancy. Special cases where high-rise residence concepts are discussed include the following:

- Section 2.2.1A discusses occupancies that are covered by the *Standards*. This includes the definition of high-rise residential and a discussion of how to determine whether a building is a high-rise residence, or low-rise residence.
- Section 5.1.1B includes a list of occupancy types that may be used to determine the lighting power density. The full definitions of these occupancies are included in Appendix G.

6.3.4 High-rise Residential Compliance

The following subsections discuss the special compliance requirements that apply to high-rise residential occupancies.

A. Mandatory Measures

The mandatory measures for envelope, mechanical and lighting, as described in Sections 3.2.1, 4.2.1 and 5.2.1, apply to high-rise residential buildings including Section 6.3.4

In addition, a special requirement applies to the lighting in high-rise residential living quarters. This requirement states that the living quarters must meet bathroom and kitchen lighting requirements that apply to low-rise residential buildings. An explanation of this requirement is included in Appendix H.

The following exceptions to mandatory measures are specific to high-rise residential buildings:

Envelope

- Manufactured fenestration products installed in high-rise residential buildings must be certified as meeting the nonresidential values for both air infiltration and fenestration U-factor. If default U-factors are used, they shall be consistent with the default values contained in Section 3.1.2I. If an NFRC certified fenestration product is used, the U-factor for commercial size categories shall be used.

Mechanical

- High-rise residential occupancies must meet setback requirements applicable to low-rise residential occupancies.

Lighting

- Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.
- Automatic shut-off controls are not required for living quarters.

Following are examples of the noteblocks that should be rewritten to actual conditions. A block note for each of the items listed should be included, even if the noteblock states "not applicable"

Note: Dwelling Units in high-rise residential buildings must comply with the following mandatory measures, per Title 24 §122(c), 130 (b) and 150(i). When this noteblock is incorporated into the permit documents or building plans, the applicable features noted shall be considered by all parties as binding minimum component performance specifications for the mandatory measures whether they are shown elsewhere in the documents or on the checklist only. This noteblock does not include nonresidential mandatory envelope, lighting, and mechanical mandatory measures, which are also applicable to High-Rise Residential buildings. See 3.2.1, 4.2.1, 5.2.1, and 6.3.4 for more examples of noteblocks for nonresidential mandatory measures.

Example 6-3 – Sample Notes: High-Rise Residential Mandatory Measures

HIGH-RISE RESIDENTIAL DWELLING UNIT SPACE CONDITIONING MEASURE
Setback Thermostats

All heating and /or cooling systems other than wood stoves shall have an automatic thermostat with a clock mechanism for at least two periods within 24 hours. §122(c) and §150(i).

HIGH-RISE RESIDENTIAL DWELLING UNIT LIGHTING MEASURE
Lighting

40 lumens/watt or greater for general lighting in kitchens and rooms with water closets; and recessed ceiling fixtures that are IC (insulating cover) approved. §130(b)

B. Prescriptive Compliance

The prescriptive requirements for envelope, mechanical and lighting, as described in Sections 3.2.2, 4.2.2F and 5.2.2, apply to high-rise residences.

The following prescriptive requirements are specific to high-rise residences:

Envelope

- Special requirements apply to the envelope in high-rise residential buildings. These requirements state that the envelope must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings. An explanation of this requirement is included in Section 3.2.2.

Mechanical

- High-rise residential living quarters are not required to have economizer controls. Section 4.2.2F contains an explanation of these requirements.

Lighting

- High-rise residential living quarters are exempt from the lighting power density requirements. Section 5.2.4A contains a discussion on exempt lighting.
- Each occupancy (other than living quarters) in the high-rise residence must comply with either the Area Category Method or the Tailored Method. These methods cannot be mixed within a permit application. See Section 5.2.2 for a more complete discussion of how to use these compliance approaches.

C. Performance Compliance

The rules for high-rise residential performance compliance are identical to the performance compliance rules for all nonresidential buildings. The area of each function of a high-rise residence is input into the program along with its corresponding envelope, mechanical and lighting features. The computer program will automatically calculate an energy budget for the standard design, and the proposed design's energy use.

A complete discussion of the performance approach is included in Section 6.1.

6.3.5 High-rise Residential Plan Check Documents

Documenting high-rise residential compliance with the *Standards* is similar to documenting compliance for other nonresidential buildings. The forms, and instructions for completing the forms, are included in Sections 3.3, 4.3, 5.3, 6.1 and Appendix H of this manual.

6.3.6 High-rise Residential Inspection

Inspecting high-rise residential for compliance with the *Standards* is similar to inspecting for compliance with other nonresidential buildings. The field inspection checklist and inspection instructions can be found in Appendix I of this manual.

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